The Islamic University of Gaza
Deanery of Graduate Studies
Faculty of Engineering
Master of Architecture Program

Studying the Principles of Window Design for Energy-Efficient Buildings in the Gaza Strip

دراسة أسس تصميم فتحات المباني الموفرة للطاقة في قطاع غزة

By

Hazem R. Dabboor

Supervisor

Dr. Ahmed S. Muhaisen

A Thesis Submitted to the Islamic University of Gaza in Partial Fulfillment of the Requirements for the Degree of Master in Architecture

November, 2011

Declaration

The work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

Acknowledgement

Firstly, I would like to thank my supervisor Dr. Ahmed Muhaisen for his important and helpful guidance from the beginning to the end of this research. I also want to thank him for his patience of teaching me scientific research techniques. Secondly, I owe many thanks to the Islamic University, which gave me the opportunity to study and to increase my knowledge. It provided many facilities which helped me greatly in this study. Last but not least, special thanks go to my parents and brothers, for their great love and support to me.

Abstract

Windows are one of the most necessary envelope elements in any building, as they provide access to views, daylight, and also function as part of the ventilation system. However, they are the weakest thermal link in a building envelope for heat gain in summer and heat loss in winter. Thus, window design has a significant impact on building energy consumption. In general, windows affect a building's thermal state by transmitting solar radiation directly into indoor spaces. This gain is beneficial in winter and undesirable in summer as it can overheat the space. Therefore, the critical design issue is to control this solar gain in relation to the summer and winter requirements.

There are four factors that control the solar gain entering through windows which are: size, orientation, glass material and shading device of windows. This research aims to examine these factors in accordance with local environmental conditions of the Gaza Strip. In order to achieve the purpose of research, an parametrical study is carried out by "IES VE" and "ECOTECT" programs to assess the effect of window on energy consumption of a typical residential building in the Gaza Strip.

The study concluded that the appropriate window design in the Gaza Strip buildings can effectively reduce the energy consumption. It found that the optimal windows orientation is by elongating the long axis of the building along east-west direction. It also concluded that the minimum percentage of windows by (10%) of the total facade area is the optimum size for all facades. The direct impact of south window is considered the worst, as it causes the largest energy consumption. In addition, the study emphasized that using advanced glazing materials with low U-value is an important factor in reducing the energy demand. It also confirmed that the horizontal device with relatively short depth is the appropriate type for south window, whereas the compound (horizontal and vertical) device with long depth is the most effective for west and east windows.

الملخص

تعتبر الفتحات عنصر رئيسي في الغلاف الخارجي للمبني سواء من الناحية البيئية أو الوظيفية أو الجمالية، فالنافذة عنصر متعدد الوظائف، من حيث توفير التهوية الطبيعية الكافية والإضاءة الطبيعية اللازمة بالإضافة إلى توفير الإطلالة الخارجية. مع ذلك تعتبر الفتحات في الجانب الحراري أضعف نقاط الاتصال بين الداخل والمحيط الخارجي للمبنى، وتؤثر بشكل كبير على الأداء الحراري للمبنى ومن ثم على استهلاك الطاقة، سواء بزيادة الفقد الحراري في فصل الشتاء أو زيادة الكسب الحراري في فصل الصيف. تأثير الفتحات على الأداء الحراري للمبنى يأتي بشكل كبير من الانتقال المباشر للإشعاع الشمسي. بالرغم أن الكسب الحراري الناتج عن هذا الإشعاع الشمسي مفيد في فصل الشتاء، لكنه غير مرغوب في فصل الصيف عندما يؤدي إلى ارتفاع درجة الحرارة داخل المبنى. لذلك فان التحكم بالإشعاع الشمسي الذي يمر خلال الفتحات يعتبر محدد أساسي في تصميم فتحات ذات كفاءة عالية في استهلاك الطاقة ودون التأثير السلبي على الراحة الحرارية لمستخدمي المبنى.

يهدف هذا البحث إلى دراسة الاعتبارات الحرارية التي يحب على المصمم المعماري اختبارها عند تصميم الفتحات في مباني قطاع غزة، والتي تتمثل في الاعتبارات التالية: موقع وتوجيه الفتحة، أبعاد وقياسات الفتحة، ونوع المادة المصنوعة منها، بالإضافة إلى دراسة كاسرات الشمس، وذلك للوصول إلى نوافذ ذات كفاءة بيئية عالية، تحقق أقصى راحة حرارية وبتكلفة اقتصادية أقل. ولتحقيق هذا الهدف فان البحث اعتمد على الدراسة المعيارية باستخدام برامج المحاكاة "IES VE" و "ECOTECT"، لدراسة تأثير المتغيرات الأربعة في تصميم الفتحات الخارجية على أحمال التدفئة والتبريد لنموذج مبنى سكني مقترح.

وقد خلصت الدراسة إلى أن التصميم الملائم للفتحات الخارجية في مباني قطاع غزة يؤدي بفاعلية إلى توفير استهلاك الطاقة. حيث تبين أن التوجيه الأمثل للفتحات هو توجيه الضلع الطويل للمبنى على امتداد المحور الشرقي الغربي. أيضا أكدت الدراسة أن استخدام أدنى مساحة من الفتحات بنسبة (10%) من إجمالي مساحة الواجهة هو أفضل خيار تصميمي لجميع واجهات المبنى، وأن التأثير المباشر للفتحة الجنوبية يعتبر الأسوأ من حيث استهلاك الطاقة. استنتجت الدراسة أيضا أن تطوير مواد زجاجية للفتحات بمعامل انتقالية حرارية (U-Value) منخفض يلعب دور مهم في توفير الطاقة المستهلكة في أحمال التبريد والتدفئة. وتوصلت الدراسة إلى أن كاسرات الشمس الأفقية بعمق قصير نسبيا يعتبر هو النوع المناسب لفتحات المبنى الجنوبية، في المقابل تعتبر كاسرات الشمس المركبة من أفقية ورأسية بعمق كبير نسبيا هو الأكثر فاعلية لفتحات المبنى الغربية والشرقية.

Contents

Figures

Tables

Chapter 1

Introduction

1.1. Background

Energy is a very important source, as it is used in all aspects of our life. Nowadays, energy consumption of non-renewable fossil fuels has increased steadily across the world with the continued growth of the population. This using of fossil sources to produce energy has adverse impacts on the environment as well as on the human health such as global warming, ozone depletion and acid rain. Moreover, these traditional types of energy are expected to run out. Thus, alternative ways which use more renewable sources must be utilized.

The Gaza Strip suffers from a serious problem in energy. It has almost no conventional energy sources except the recent exploration of the gas field near the Gaza Strip beach, which can contribute in reducing the crisis when start working. In addition, it depends mainly on the electricity and fossil fuels, which are bought from (Israel) with high prices that are not appropriate with the bad economic situation of the people. Besides the high price, the Gaza Strip has been suffering from a lack of fossil fuels and cut of electricity supply for several years as a result of the (Israel) occupation procedures (Muhaisen, 2007).

In the Gaza Strip, the residential buildings consume the large part of the overall energy consumption, which is estimated to be 70% of the total amount of energy consumption according to Muhaisen (2007). Thus, this sector should be the field of study for researchers in an attempt to rationalize energy consumption through integrating renewable energy sources in the design of buildings. This can be done by two methods. The first is through active design systems, which employ hardware and mechanical equipment to collect and transport heat such as, the use of photovoltaic cells. The second is through passive design systems, which collect and transport heat by non-mechanical means, such as control the amount of solar radiation entering through windows (Mazria, 1979).

One of the passive solar techniques is the energy-efficient windows, which is defined as windows that provide good lighting during the day and good thermal comfort both during day and night at minimum demand of energy. Because windows provide less resistance to heat flow than walls, ceilings, and floors of the building, it is considered as one of the important elements that affect the building energy consumption. Although windows present a small area of the building, they have the greatest effect on heat loss and gain, and air leakage. According to Kaklauskas (2006) windows are responsible for about 30% of the heat loss in buildings. This effect of windows on building energy requirements depends on several factors which are size, orientation, thermal properties of glass material and shading devices (Ingersoll, 1979).

This thesis focuses on these four major factors to study their effects on building energy requirements to achieve more energy efficient windows.

1.2. Importance of the study

This study is considered one of a few studies that investigate the design of windows of buildings in the Gaza Strip to be in accordance with the design principles of energy efficient buildings. The importance of the study can be summarized as mentioned in the following points:

- Finding solutions and practical steps to assist in rationalizing the energy consumption of buildings in the Gaza Strip.
- Keeping up with the tendency all over the world to reduce the dependence on conventional energy in buildings, and to use more renewable energy.
- Recovering the limitation of studies that pay attention to the issue of window design in the Gaza Strip buildings and to its effect on thermal comfort and energy consumption.
- Motivating the scholars and decision-makers to benefit from this study. In addition, encouraging them to study the other design principles of energy efficient buildings in the Gaza Strip.

1.3. Research objectives

The main objective of this research is to determine the best parameters of window design in terms of size, orientation, construction material, and shading device to suit the local environmental conditions of the Gaza Strip. In addition, This research aims to achieve a number of other specific objectives, including:

- To highlight the energy situation of the world by estimating the global energy consumption.
- To identify the problem of energy shortage in the Gaza Strip and its negative impact on all aspect of Palestinian life.
- To discuss the potential solutions of available renewable energy sources such as solar and wind energies that can contribute to solve the energy problem.
- To find out the basic principles of thermal comfort, and its personal and environmental determinants.
- To study the strategies of energy-efficient building design, which include the planning aspects, or building envelope, and to clarify the effect of these strategies on thermal comfort and energy consumption.

- To examine the energy-efficient windows and its principles design which include windows to wall ratio, orientation, construction material and shading device.

1.4. Research limits

This thesis focuses on residential buildings in the Gaza Strip, that consumes the largest part of energy, which is estimated to be 70% of the total amount of energy consumption according to Muhaisen (2007). It focuses on the one-storey residential building. The most common structural system of these buildings are often built with contemporary materials, mainly reinforced concrete. The walls are made of concrete hollow blocks, while the windows are single-glazed with aluminum frame. The climate of the Gaza Strip is characterized by its location in hot humid region specifically on longitude 34^0 26' east and latitude 31^0 10' north.

1.5. Problem statement

Windows of buildings in the Gaza Strip vary in size and form. Also in one building, it is noticed that there are similar sizes and dimensions for the different orientations of building facades. Generally, this phenomenon refers to the designers who usually pay attention to the aesthetic and architectural aspects during the design stages, more than the environmental aspects. This usually affects negatively on the thermal performance of buildings and increases the consumption of electrical energy required for artificial condition systems.

In addition, nowadays the world has been suffering from the problem of global warming, which directly related to the increasing consumption of fossil fuels. The purpose of this research is to find solutions, which lead to the thermal comfort of building occupants with less conventional energy consumption. This is investigated through studying the principles of window design, which match the environmental conditions of the Gaza Strip.

1.6. Hypothesis

The appropriate windows design of buildings in the Gaza Strip to suit environmental conditions will effectively lead to reduce the energy consumption as well as meet the requirements of thermal comfort.

1.7. Methodology

The research will be carried out depending on the approach of making a parametrical study using computer simulation programs.

Nowadays, there are many computer simulation programs used to examine the thermal performance of buildings. This research will use two simulation tools. The first tool is Integrated Environmental Solutions (IES) virtual environment program, which can perform a dynamic thermal simulation using hourly weather data. The second tool is Ecotect program, which is used as a validation tool. Both IES VE and Ecotect offer a wide range of simulation applications during the earliest stages of design such as calculating annual, monthly heating and cooling loads.

The parametrical study consists of three parts. The first part includes description of the study model, define the study questions, determine thermal performance parameters and collect weather data needed. Then the simulation and validation tools are selected in the second part. Finally, appropriate design parameters of size , orientation, construction material and shading device are analyzed and selected with taking into consideration the value of energy efficiency and thermal comfort as an indicators of the thermal performance.

1.8. Structure of the thesis

This research consists of two main parts. First part is the literature review, which focuses on energy situation in the world and Gaza Strip, energy-efficient building design principles, definition and functions of windows, as well as principles of energy-efficient windows which include size, orientation, construction material and shading device. The second part includes parametrical study to examine the impact of windows on the overall energy consumption. Fig. (1.1) summarizes the main structure of this research.

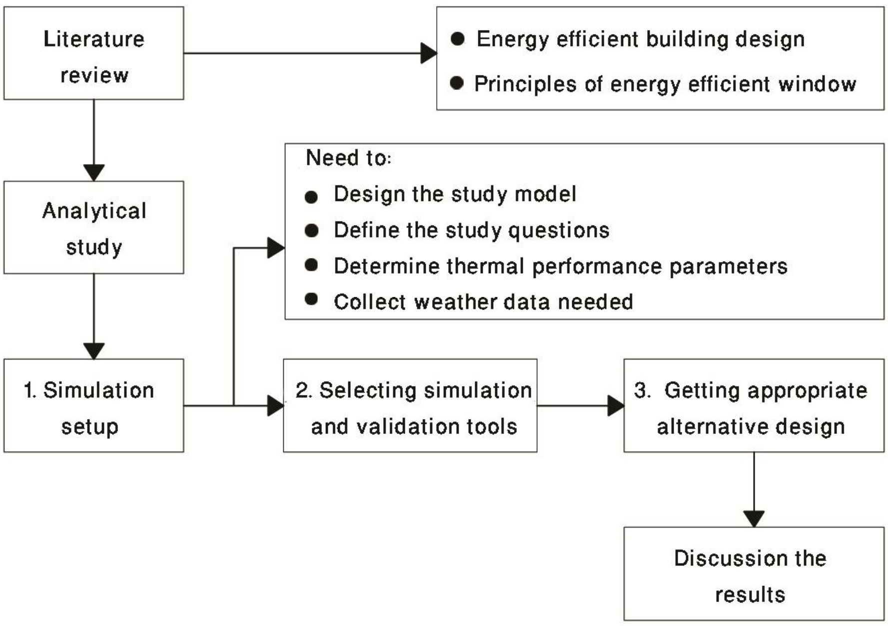


Fig. 1.1 : Structure of the research

This thesis aims to identify the optimum design alternatives and to determine the energy saving rate as a result of using this optimum design, and it is structured into six chapters:

Chapter 1 states the research background, importance, objectives, limitation, problem, hypothesis, methodology as well as a previous studies.

Chapter 2 presents a literature review about the energy and building design including the energy situation in the world with special focus on the Gaza strip. In addition, the basic principles of energy efficient building design are discussed in this chapter.

Chapter 3 introduces a literature review about the definition and function of windows. The principles of energy efficient windows including size, orientation, glazing material and shading devices are involved in this chapter.

Chapter 4 investigates the impact of window design on the overall energy consumption through three parts: first part describes the simulation setup, second part discusses selecting the simulation and validation tools, last part analyses the appropriate design alternatives.

Chapter 5 investigates the impact of shading devices located on south, west and east windows on the overall energy consumption. The overshadowing effect of adjacent buildings on windows is also studied in the chapter.

Chapter 6 gives a conclusion about the design principles of energy efficient windows. Some recommendations are provided in this chapter as well.

1.9. Previous studies

Several Studies have investigated the effect of windows on building energy requirements and thermal comfort conditions, for example:

Marrero and Oliveira (2010) studied the effect of louver shading devices on building energy requirements, which were quantified in the cooling and heating seasons for different windows and louver areas, under climatic conditions of Mexico (Mexico), Cairo (Egypt), Lisbon (Portugal), Madrid (Spain) and London (UK). Also, operative and indoor temperatures were calculated through simulations using TRNSYS software, whereas the model for the shading geometry study was solved with EES software. The research concluded that the integration of louver shading devices in the building leads to indoor comfortable thermal conditions and may lead to significant energy savings, by comparison to a building without shading devices.

Monna and Masera (2010) investigated the effects of windows wall ratio and orientation design alternatives on comfort and energy efficiency using computer simulation programs. The study focused on office buildings in hot, arid climate. The simulations were run for the different orientations, and the following glazing ratios: 30%, 50%, 70% and 90% were considered. The study concluded that the large glazing areas are possible at north as the direct solar radiation passing through is limited. The south facade receives its light at a steep angle, so the intensity of solar radiation on the facade is smaller, and efficient shade can be provided. In summer, a large amount of solar radiation enters the east and west facades at a shallow angle, and special screening technologies and glass are needed beside a windows/wall ratio consideration.

Gutierrez and Labaki (2007) carried out an experimental study about thermal performance of different fixed shading devices. The typology and materials were selected considering the elements used in modern architecture buildings of Brazil, between the 1930 and 1960 decades. The experimental setup consists of six test-cells, each one with one kind of the shading device testing samples, and a meteorological station. The longer facades were oriented to north and south. The results show the relation of orientation, typology and material of the devices in test. The most significant response was the horizontal concrete louver on north facade. In spite of the good insulation properties of wood, the concrete devices presented the best results.

Persson and et al. (2006) examined how decreasing the window size facing south and increasing the window size facing north in the low energy houses would influence the energy consumption and maximum power needed to keep the indoor temperature between 23^0 C and 26^0 C. Different orientations have been investigated as well as the influence of window type. The dynamic building simulation tool, DEROB-LTH, was used. The results showed that the size of the energy efficient windows does not have a major influence on the heating demand in the winter, but is relevant for the cooling need in the summer. This indicated that instead of the traditional way of building passive houses it is possible to enlarge the window area facing north and get better lighting conditions. To decrease the risk of excessive temperatures or energy needed for cooling, there is an optimal window size facing south that is smaller than the original size of the investigated buildings.

Datta (2001) investigated the effect of fixed horizontal louver shading devices on thermal performance of building by TRNSYS simulation. The study was conducted for four different cities in Italy. The results confirmed that shading factor varies with time of day and is different for summer and winter. For example, for Milan it was found that 70% of gain is cut off in summer, while only 40% is cut off in winter by using optimum shading, which is desirable. Also, it indicated that external fixed horizontal louvers of proper design for south windows are effective in not only reducing cooling loads of a building in summer but overall annual primary energy loads of a building.

The previous mentioned studies discussed different factors to examine the effect of window design on energy consumption. These factors include shading devices, windows wall ratio, orientation and material. The studies consider the energy demand as an indicator to determine the optimum design. The computer programs are commonly used as a simulation tools in most of the studies. In addition, the experimental study can be used as an effective tool in this type of studies. It has been noticed that the focus of the studies is different according to building type and climate conditions, therefore these two factors should be taken into account to limit the study area. It is found that each study focused on one or two of window design factors, so there is a need to examine all factors in the same conditions, which will be carried out in this study.

Chapter 2

Energy and Building Design

Introduction

Energy and building are interlinked, because the large part of energy is consumed by buildings. This consumption is estimated to be 70% by the residential buildings of the Gaza Strip (Muhaisen, 2007). Therefore, the sector of buildings should be the focus of study for researchers in an attempt to reduce the energy consumption. This can be done through design energy efficient building which improve comfort levels of the occupants with low consumption of traditional energy sources.

This chapter is carried out to introduce a literature review about the global and local energy situation in terms of consumption rates, available energy resources and alternative solutions. Then, the chapter discusses the possibility of reducing the energy consumption of buildings through passive design methods, which include the planning principles, building envelope and fenestration principles, passive cooling techniques, and passive heating techniques.

2.1. Energy situation in the world

Energy is essential to economic and social development and improved quality of life in all countries. It is used in transportation, agriculture, industries, buildings, and almost all aspects of modern life. The energy resources can be divided into fossil fuels, renewable resources, and nuclear resources. The current world demand depends mainly on the conventional energy which pollute the environment. The renewable energy sources presents alternative sources but they need more development to compete the fossil fuels sources.

The main objective of this section is to describe the global energy consumption. Then, it discusses the environmental problems of conventional sources such as acid rain, ozone depletion, and greenhouse effect. Finally, it identifies some solutions to the current environmental problems, focusing on renewable energy sources.

2.1.1 Global energy consumption

World energy demand is expected to expand by approximately 60% from 2002 to 2030 with an average annual increase of 1.7% per year, see Table (2.1). By 2030, demand will reach 16.5 billion tons of oil equivalent (toe) compared to 10.3 billion toe in 2002 (Bilen, 2008).

The share of fossil fuels will increase slightly, from 80% in 2002 to 82% in 2030. The share of renewable energy sources will remain flat, at around 14%, while that of nuclear power will drop from 7% to 5% (Bilen, 2008).

Oil will remain the largest fuel in the global energy demand, even though its share will fall marginally, from 36% in 2002 to 35% in 2030. Demand for oil is expected to grow by 1.6% per year, from 77 mb/d (Millions of Barrels per Day) in 2002 to 90 mb/d in 2010 and 121 mb/d in 2030 (Bilen, 2008).

Table 2.1 : World total consumption (Mtoe)

Source: (Bilen, 2008)

	1971	2002	2010	2030	2002–2030 (%)[a]
Coal	617	502	516	526	0.2
Oil	1893	3041	3610	5005	1.8
Gas	604	1150	1336	1758	1.5
Electricity	377	1139	1436	2263	2.5
Heat	68	237	254	294	0.8
Biomass and waste	641	999	1101	1290	0.9
Other renewable	0	8	13	41	6.2
Total	4200	7075	8267	11,176	1.6

[a] Average annual growth rate.

Natural gas will grow at a steady rate of 2.3% per year. By 2030, gas consumption will be about 90% higher than 2002. The share of gas in total primary energy demand will increase from 21% in 2002 to 25% in 2030. On the other hand, Coal demand is expected to increase by 1.5% per year between 2002 and 2030. By the end of the 2004, coal demand will be about 50% higher than at 2002. However, the share of coal in total primary energy demand will fall slightly from 23% to 22%. The nuclear power share of world primary demand is expected to drop from 7% at 2002 to 6% in 2010 and to 5% by 2030. However, These prospects are may considered to be uncertainty. Possible changes in government policies on nuclear power could lead to nuclear power playing a much more important role than expected here (Bilen, 2008).

The growing level of energy consumption and production is mainly influenced by two factors. These factors include population growth and economic development. Since the Industrial Revolution, energy consumption has been continuously increasing. The global economy is expected to grow by 3.1% a year, on average, to 2020. Global gross domestic product (GDP) is expected to rise from $33 trillion in 1997 to $49.9 trillion in 2010 and $67.3 trillion by 2020. World population is also expected to grow from 6 billion 1999 to 8 billion in 2020. World population is currently growing at an annual rate of 1.4% per year. This expanding economy and population will contribute significantly to the growing global energy demand (Salameh, 2003).

2.1.2 Environmental problems of conventional energy

Using fossil conventional sources to produce energy causes several environmental impacts as a result of the increased amount of gaseous pollutants, which radiate during combustion process. These environmental problems include global warming air pollution, acid precipitation, ozone depletion, forest destruction and emission of radioactive substances. A summary of the pollutants and their environmental impact is tabulated in table (2.2) (Bradshaw,2006).

Table 2.2 : Main gaseous pollutants and their impacts on the environment

Source: (Dincer, 2000)

	Greenhouse effect	Ozone depletion	Acid rain
Carbon monoxide (CO) and carbon dioxide (CO_2).	+	+ / -	
Methane (CH_4)	+	+ / -	
Nitric oxide (NO) and nitrogen dioxide (NO_2).		+ / -	+
Nitrous oxide (N2O)	+	+ / -	
Sulfur dioxide (SO_2)	-	+	
Chlorofluorocarbons (CFCs)	+	+	
Ozone (O_3)	+		+

where (+) stands for positive contribution and (-) stands for variation with conditions and chemistry, may not be a general contributor

The three major environmental problems that are internationally known are discussed in more detail below:

1. Greenhouse effects and global warming

The greenhouse effect is the rise in the temperature of earth because greenhouse gases such as CO_2, CH_4, CFCs, N2O, ozone, and peroxyacetylnitrate in the atmosphere trap the heat radiated from Earth's surface. A diagrammatic representation of this global climate change problem is illustrated in fig. (2.1).

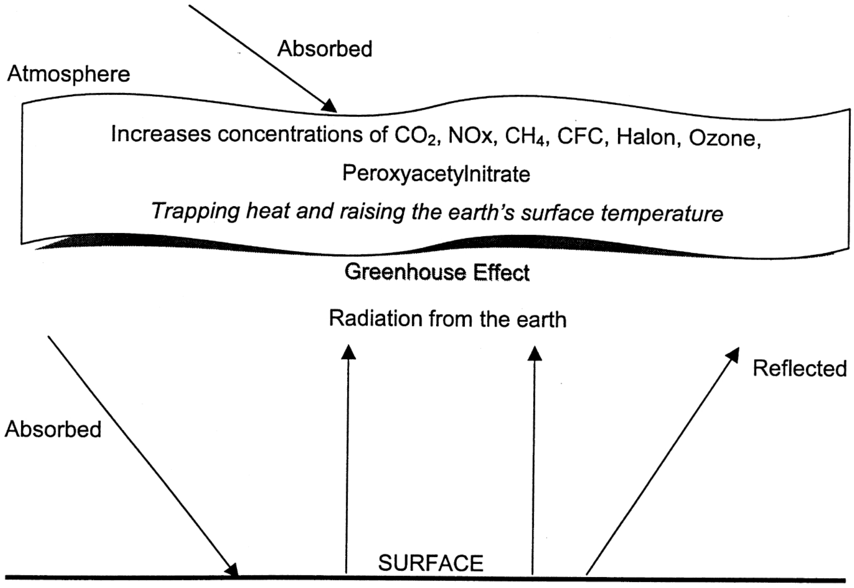


Fig. 2.1 : A Diagrammatic illustration of greenhouse effect
Source : (Dincer, 2000)

According to Demirbas (2004) the main greenhouse gas associated with global warming is carbon dioxide (CO_2). About 98% of carbon emissions result from fossil fuel (coal, oil, and natural gas) combustion. In 2005, it was estimated that CO_2 contributes about 50% to the greenhouse effect. Fig. 2.2 shows the world CO_2 emissions between 1990 and 2020. In addition, contribution each gas to the greenhouse effect. According to Bradshaw (2006) the global warming causes increasing the temperature of the earth, raising sea levels as more of the polar ice melt, and coastal flooding. In addition, change climates affecting agricultural production of some areas.

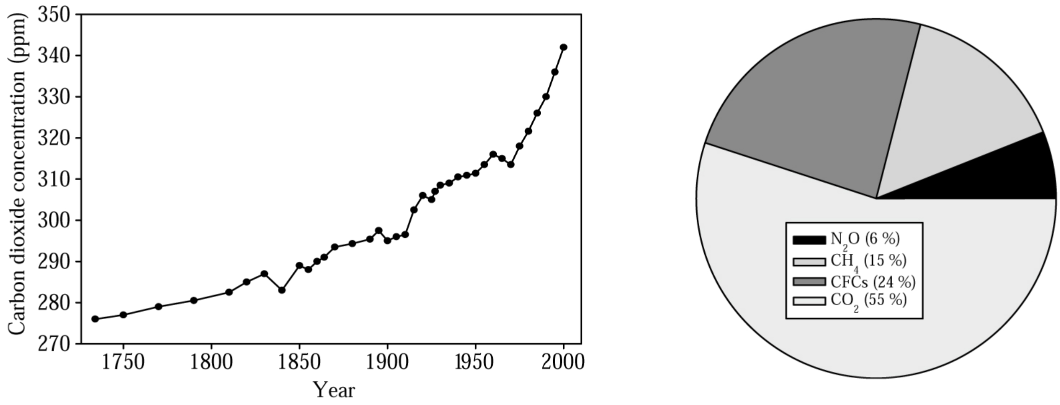


Fig. 2.2 : World CO_2 emissions between 1990 and 2020 in the left and contribution each gas to the greenhouse effect in the right

Source : (Demirbas, 2004)

2. Ozone depletion

The earth is enveloped by a layer of ozone gas located in the stratosphere at altitudes between 12 and 25 km. The ozone plays major role in protecting the earth people through absorption of harmful ultraviolet (UV) radiation from the sun (Kalogirou, 2004). The global environmental problem of Ozone depletion is caused by release of chlorofluorocarbon (CFC) refrigerants that have been used in building and automobile air conditioning. These CFC molecules rise to the upper atmosphere and release their chlorine atoms which break down the ozone. Ultraviolet rays which reach the earth's surface increase the risk of skin cancers, eye cataracts and other dangers consequence (Bradshaw,2006).

3. Acid rain

The acid rain occurs when sulfur dioxide (SO_2) and nitrogen oxides (NOx) combine with water vapor in the atmosphere and fall as rain. These gases are produced from burning fossil fuels including petrol, diesel, and coal in automobiles, homes, and industries (Demirbas, 2004). Falling acid rain on the earth causes large damage to water, forest, soil sources and human health. It can also corrode buildings and be hazardous to human health. The possible solutions to reduce acid rain are by reducing energy consumption, or by cleaning the fossil fuels before burning (Kalogirou, 2004).

2.1.3 The potential of renewable energy sources

In the last few decades, the search for new alternative energy systems instead of conventional fossil fuels has increased greatly, because the use of conventional energy sources, as mentioned in the previous sections, will not be able to supply extra demand on energy in the next decades with steady increase of population and economic development. In addition, the continued use of conventional energy sources will expand the environmental problems of global warming, acid rain, greenhouse effect, etc. This beside the fact of fossil fuels are not available in every country because they are unequally distributed over the world. Thus, there is urgency needs to find alternative to cover the shortage on energy without negative impacts on environment.

In this respect, renewable energy sources (RES) appear to be one of the most efficient and effective alternatives. (RES) include biomass, hydropower, geothermal, solar, wind and marine energies. (RES) are expected to play an important role in the future energy. They are readily available in nature (Demirbas, 2004). The significant advantages of (RES) that They are sustainable, found everywhere across the world found in contrast to fossil fuels, and environmentally clean. There are many benefits of using renewable energy systems: energy saving by reduction in consumption of electricity or fossil fuels that are used conventionally to provide energy, provide jobs vacancies and support the economic sector, and the most important benefit of renewable energy systems is the decrease of environmental pollution (Kalogirou, 2004).

The disadvantages of renewable energy are its variability and low density in some locations. For example, the earth surface do not receive the same amounts of solar radiation and the places far away from the equator do not have enough irradiation intensity to generate the system. Another disadvantage, renewable energy sources require high initial cost. However, this cost is lower than conventional energy in the medium term. Thus, renewable energy is still the best alternative available instead of conventional sources (Sen, 2008).

According to Panwar (2011), in 2010 renewable energy resources supplied 16.6% of the total world energy demand. By 2040, they are projected to contribute 47.7%, see table (2.3) presents the global renewable energy scenario from 2001 to 2040.

Table 2.3 : Global renewable energy scenario by 2040

Source: (Panwar, 2011)

	2001	**2010**	**2020**	**2030**	**2040**
Total consumption (million tons oil equivalent)	10,038	10,549	11,425	12,352	13,310
Biomass	1080	1313	1791	2483	3271
Large hydro	22.7	266	309	341	358
Geothermal	43.2	86	186	333	493
Small hydro	9.5	19	49	106	189
Wind	4.7	44	266	542	688
Solar thermal	4.1	15	66	244	480
Photovoltaic	.1	2	24	221	784
Solar thermal electricity	0.1	0.4	3	16	68
Marine (tidal/wave/ocean)	0.05	0.1	0.4	3	20
Total RES	1,365.5	1,745.5	2,964.4	4289	6351
Renewable energy source contribution (%)	**13.6 %**	**16.6%**	**23.6%**	**34.7%**	**47.7%**

Renewable energy technologies produce marketable energy by converting natural phenomena into useful forms of energy. These technologies use the suns energy and its direct and indirect effects on the earth (solar radiation, wind, failing water and various plants), gravitational forces (tides), and the heat of the earth's core (geothermal) as the sources from which energy is produced. The technologies of renewable energy sources and their various types will be discussed in the following section (Demirbas, 2004).

2.1.4 Renewable energy sources

The following section discusses five types of renewable energy sources which are biomass, hydropower, wind, geothermal and solar energies:

1. Biomass energy

Biomass is the solar energy which is absorbed and converted into chemical form in plant and animal materials during photosynthesis process. It is the first type of renewable resource used for energy generation returned to the stone age people who gathered the wood for heating purpose. At the present time, Biomass is more than just wood, it includes straw, animal dung, vegetable oil, biodiesel and biogas which can be used as a renewable energy source (Bilen, 2008). According to Demirbas (2004) biomass energy represents approximately 14% of the world energy consumption. Its production from wood and wood wastes is (64%), followed by solid waste (24%), agricultural waste (5%) and landfill gases (5%).

There are three ways of using this energy, It can be burned to produce heat and electricity, it can be changed to gas fuels such as methane, hydrogen and carbon monoxide, or it can be changed to a liquid fuel. Liquid fuels, also called bio-fuels, include mainly two forms of alcohol: ethanol and methanol (Demirbas, 2004). The different between burning of biomass and combustion of fossil fuels is that biomass releases no more CO^2 than the plants have previously absorbed from the air (Bilen, 2008).

2. Hydropower energy

Hydropower energy uses falling water to generate electricity energy. It is considered as non-polluted energy. When it produces energy it produces only water as waste. The most important advantage of this technology is the low costs of electricity generation. In addition, in contrast to solar or wind power plants, it produce energy without interruption as long as there is enough water in the reservoir (Bilen, 2008). There are two types of Hydropower plants. The small-scale hydropower systems which include micro hydropower systems (MHP) with capacities below 100 kW and small hydropower systems (SHP) with capacity between 101 kW and 1 MW. The second type is large-scale hydropower which supplied 20% of global electricity (Yuksel, 2008).

3. Wind energy

Wind can be used to generate electricity by using wind turbines that convert the kinetic energy of wind into electricity. This source of energy is nonpolluting and available in many areas. An advantages of wind power that they generate electricity whenever the wind blows. In contrast, the disadvantage that they do not generate any electricity when there is no wind. Thus, this type of technology requires enough open areas and wind velocity. At the present time, wind turbines are becoming more efficient. Production of electricity by wind has risen from zero in the early 1980s to more than 7.5 TWh per year in 1995. Fig. (2.3) shows the growth in world wind turbine capacity (Demirbas, 2004).

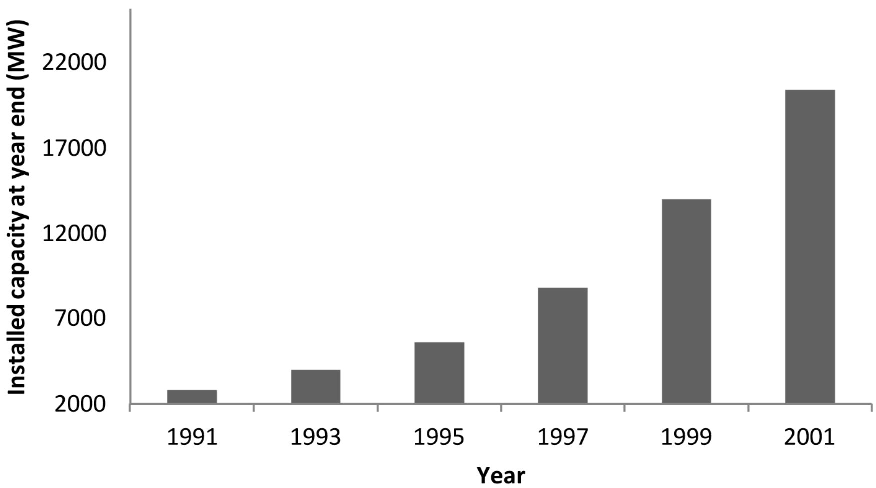


Fig. 2.3 : Growth in world wind turbine capacity
Source : (Demirbas, 2004)

4. Geothermal energy

Geothermal energy is the using of heat inside the earth for heating and electricity generation. It covers only 0.5% of the total primary energy supply. There are two different methods for using geothermal power. The first one is the hydrogeothermal method, where naturally heat the water reservoirs which are tapped underground. The hot groundwater can be used for heating, and also for the generation of electricity. The second method is the hot dry rock method, which uses the geothermal heat contained in rock to heat the water which is pumped into hot rock and then returns to the surface (Bilen, 2008).

4. Solar energy

Another major renewable energy source is solar energy. According to Salameh (2003), in less than one week, the solar energy which is received by Earth surface is more than world's total fossil fuel reserves. However, at present, solar energy covers only 0.05% of the total of global energy demands and photovoltaic (PV) power generates less than 1% of total electricity supply. This is because of solar power still considered the most expensive type of renewable energies (Solangi, 2011).

The major component of any solar system is the solar collector. This collector is special kind of heat exchangers that transform solar radiation energy to internal energy of the transport medium (Demirbas, 2004). Generally, Solar energy can be used in two different ways: to generate heat (solar thermal application) or directly to generate electricity (PV application): In solar thermal applications water or another liquid runs through tubes that are heated by the sun. The hot water can be used for heating or can be used indirectly as water vapor for generating electricity (Bilen, 2008).

In PV applications the energy of the sunlight is directly converted into electricity. This needs special solar cells which are made of expensive silicon. However, scientist expects that solar cells could be made from organic matter, which will be cheaper. Then, solar cells will be efficient and economical enough to be competitive against all other types of energy (Bilen, 2008).

2.2. Energy situation in the Gaza strip

As shown in fig. (2.4), the Gaza strip is located at the south-west area of Palestine. It expands along the Mediterranean Sea with 40 km long and between 6 and 12 km wide. The total area of the Gaza strip is estimated at 365 km^2. Its height above sea level reach 50 m in some locations. It is located on Longitude 34^o 26' east and Latitude 31^o 10' north (Ministry of Local Government, 2004).

Fig. 2.4 : The Gaza strip map
Source : (Wikipedia, 2011)

The Gaza strip depends on three main sources of electricity supply including (Israeli) Electricity Company, Egyptian Electricity Company, and local Gaza Power Plant. Also, it imports the fossil fuels by two ways either directly from Israel or indirectly (by tunnels) from Egypt. Fig. (2.5) obviously shows the electricity load required for the Gaza strip from 2001 to 2010. It's clear that the electricity needs increase by about 10-15 MW annually, as a result of the natural population growth and the expansion in the different sectors requiring electricity supply (Muhaisen, 2007).

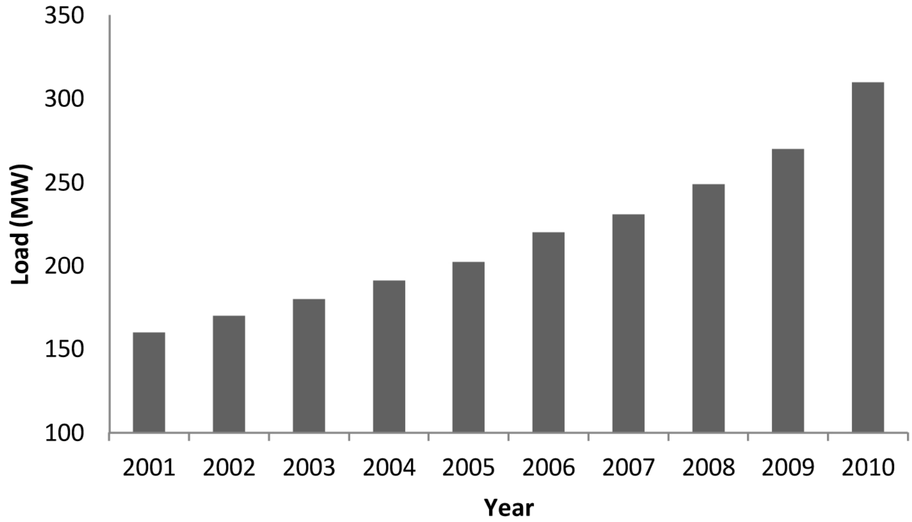


Fig. 2.5 : The electricity load required for Gaza strip from 2001 to 2010
Source : (Muhaisen, 2007)

The significant exploration of the gas field near the Gaza strip beach can play important role in the development of energy sector in the Gaza strip. There are a positive indicators for existence of approximately 50-60 billion m3 of natural gas in this field. This massive amounts of natural Gas is enough to meet the Palestinians requirements of gas for 30 years, while the surplus will be exported. Unfortunately, the project has not been implemented yet due to the bad political status (Muhaisen, 2007).

Gaza power plant consists of 6 turbines, four of them work on either light fuel oil or gas and two are steam turbines. Although its real total capacity is 140 MW, it generates just 90 MW. Bombing the plant on June 28th 2006 by Israel caused a large damage and the production decrease from 90 MW to 30 MW. This reduction affects negatively all areas of the Palestinians life.

Unfortunately, the main problem of energy in the Gaza strip is that it has almost no conventional energy sources. This problem becomes worse by the high density pollution of the Gaza strip and the difficult political status caused by (Israel) occupation. According to Kandeel (2010) the Gaza strip needs (270) MW of electricity. The available supply is (197) MW. The large share of this supply about (60%) with an average load (120) MW is provided by (Israeli) Electricity Company. Locally, about (32%) with an average load (60) MW is provided by Gaza Power Plant. In addition, about (8%) with an average load (17) MW is provided by Egyptian electric company.

In the light of previous statistics, the Gaza strip has been suffering from a real shortage in electricity supply estimated by 25%. The result is cutting of electricity supply for several hours per day which affect negatively on all aspects of the Palestinians life and make it very hard. This shortage rate of electricity supply will be increased by the time if other options is not found. One of the available and considerable options in the Gaza strip is renewable energy sources, particularly solar and wind energy.

2.2.1 Potential of using Renewable Energy in the Gaza strip

Using renewable energy will contribute to reduce the need of conventional sources and save the environment from harmful effects. Mainly, there are two types of renewable energy available in the Gaza strip:

1. Solar energy

The Gaza strip has a relatively high solar radiation. It has approximately 2861 of sunshine hours across the year with an average solar radiation of (5.33) kWh/m^2 (Palestinian Energy Authority, 2010). This refers to its location near the hot dry region of the world. Solar energy can be used in different applications. Fig. (2.6) shows the most popular application of solar energy used in the Gaza strip which is the solar water heater (SWH). According to Muhaisen (2007) about 70% of residential buildings in the Gaza strip are integrated with this solar water heating systems.

Fig. 2.6 : The common domestic water heating system in Gaza strip
Source : (Wikipedia, 2011)

2. Wind energy

As table (2.4) shows, the annual average wind speed in the Gaza strip is 3.8 m/s, which is relatively low. Thus, it is not enough to generate sufficient electrical energy. This low speed may be suitable for small residential wind turbines that can be integrated on building to generate electricity .

Table 2.4 : Wind speed and potential in the Gaza strip
Source: (Kandeel, 2010)

Location	Annual Wind Speed (m/s)	Wind Potential (kwh/m²) Elevation 10m	20m	40m
Gaza strip	2.9	152	201	261

2.3. Energy efficient building design

The previous sections discussed the global and local status of energy. It is clear that there is a serious problem in energy not only in Gaza strip but also in all over the world. This problem consists of possible shortage of conventional energy in the future and also the negative environmental impacts of these sources. Thus, the issue of energy is becoming more and more important in today's world. Because of buildings are one of the most significant energy consumers, there are several attempts to solve the problem through design low energy building which is known as energy efficient building design.

Several studies have defined the energy efficient buildings. All of these definitions discuss the same concept which based mainly on two objectives of improving comfort levels of the occupants and minimizing the consumption of traditional energy sources. According to Ahsan (2009), energy efficient buildings can be defined as ‘‘buildings maintain the best environment for human habitation while minimizing the cost of energy’’.

Majumda (2002) classifies four primary steps in energy efficient buildings approach to meet the occupant's need for thermal comfort at low levels of energy consumption, as mentioned below:

- Integrate solar passive techniques in a building design to minimize load on conventional systems (heating, cooling, ventilation, and lighting).
- Design energy efficient lighting and HVAC (heating, ventilation, and air-conditioning) systems.
- Use renewable energy systems (solar photovoltaic systems , solar water heating.
- Use low energy materials and methods of construction and reduce transportation energy.

Generally, energy efficient buildings can be achieved through two approaches which are active and passive. The active system employ hardware and mechanical equipment to collect and transport heat. In contrast, the passive system collect and transport heat by non-mechanical means. In the other words, the specific different between two systems is that the passive system operates on the energy available in its immediate environment while the active system imports energy, such as electricity, to power fans and pumps which make the system work (Mazria, 1979). In this thesis, the discussing focuses on the principles of passive design approach.

Before going into the details of principles design of energy efficient building. It is important to introduce the topic of thermal comfort that describe the interactive relation between humans and surrounding environment. It also consider as important one of thermal performance parameters in buildings.

2.3.1 Determinants of thermal comfort

According to Ampofo (2004) thermal comfort is defined as ‘‘that condition of mind which expresses satisfaction with the thermal environment’’. This satisfaction with the thermal condition is dependent on the balance between the heat produced or received by the body, and heat lost from the body to the surrounding environment.

Continuously, the human body produces heat by its metabolic processes. The average of this heat is about 100W, and it can vary from about 70W in sleep to over 700W in heavy work (Szokolay, 2004). Part of this heat must be transferred to the environment because human body needs constant internal temperature to energize all process of human systems. Thus, there is a continuous exchange of heat between human bodies and the surrounding environment. This heat exchange occurs in four different ways: through radiation, convection, evaporation and sometimes conduction (Baker, 1987).

- **Radiation:** it is the net exchange of radiant energy between two bodies across an open area. The human body gains or losses radiant heat depends on the temperature difference between the surface of the body temperature and the surrounding surfaces bodies.

- **Conduction:** the conduction heat loss or gain occurs through contact of the body with physical object such as the floor and chairs.

- **Convection:** which is the transference of sensible heat to or from the body. The faster the rate of air movement, the larger temperature different between the body and surrounding air, the greater the rate of heat transfer.

- **Evaporation:** as a cooling mechanism, sensible heat here is flowed from the skin to the surrounding air. The amount of this sensible heat depends upon the temperature different between the skin and air.

These ways are illustrated in fig. 2.7, which also shows the relative percentage in a normal comfort situation.

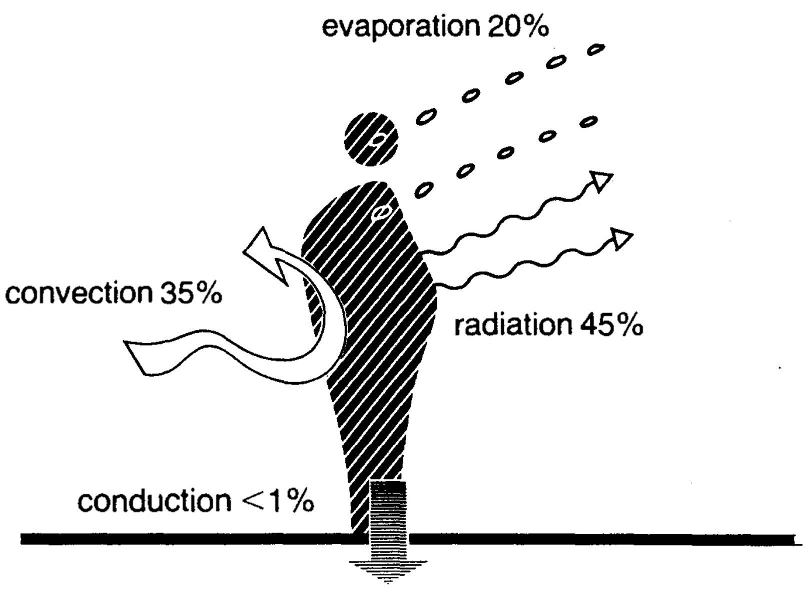


Fig. 2.7 : The mechanisms of heat loss from the body
Source : (Baker, 1987)

People feel thermal comfort differently depending on their particular conditions. The parameters affecting thermal balance are divided into environmental and personal determinants. The following discussion concentrates on these parameters (Bradshaw,2006):

1. Environmental Determinants

- **Air temperature**: the temperature of the air surrounding the human body is the most important environmental factor. There is a continuous process of heat exchange between a person and the air. The air temperature determines the rate at which heat is lost to the air by both convection and evaporation. That depends on the difference in temperature between the skin and the surrounding air (Bradshaw,2006).

- **Air movement:** the movement of air varies according to its direction and velocity which is measured by (m/s). This air movement across the body has a significant effect on the evaporation process of moisture from the skin and also has effect on heat loss. It accelerates the heat flow to and from the body by both convection and evaporation, thus it is producing a cooling effect.

- **Relative Humidity (RH):** Water heated by the human body evaporates to a vapor and absorbed in the air. This process transfer heat from the body to environment and cooling the body. Relative humidity (RH, %) is the amount of moisture in the air and it determines the rate of evaporation process mentioned above.

- **Mean radiant temperature (MRT):** Heat is exchanged by radiation between all bodies. Radiation exchange depends on the temperature of surrounding surfaces, measured by the MRT. The temperature of the human body is influence by this radiant temperature either through heat lost or gained.

2. Personal Determinants

- **Clothing:** insulation properties of clothing are an important factor in body heat loss and thermal comfort according to its type and thickness. This insulation is measured by the unit called "clo" quantified (0.155 m^2.K/W).

- **Activity level:** as a part of organic process in human body, the chemical energy is converted into heat and mechanical work which known as metabolic rate. This rate is measured by the unit of "met" (1 met equal 58.2W/m^2) and different according to the type of human activity.

In lights of the previous discussing of the thermal comfort determinations, it can identify the comfort zone which describe the acceptable comfort conditions. The comfort zone is not an absolute value for everyone, but it different depending on both environmental and personal factors. Fig. 2.8 shows Olgyay's bioclimatic chart modified for hot humid climates. The new triangle shape on the right of the original one is the required comfort zone. It clarifies that comfortable temperature ranges from about 25°C to 31.5°C and the relative humidity ranges from about 62.2% to 90% (RH) (Chenvidyakarn, 2007).

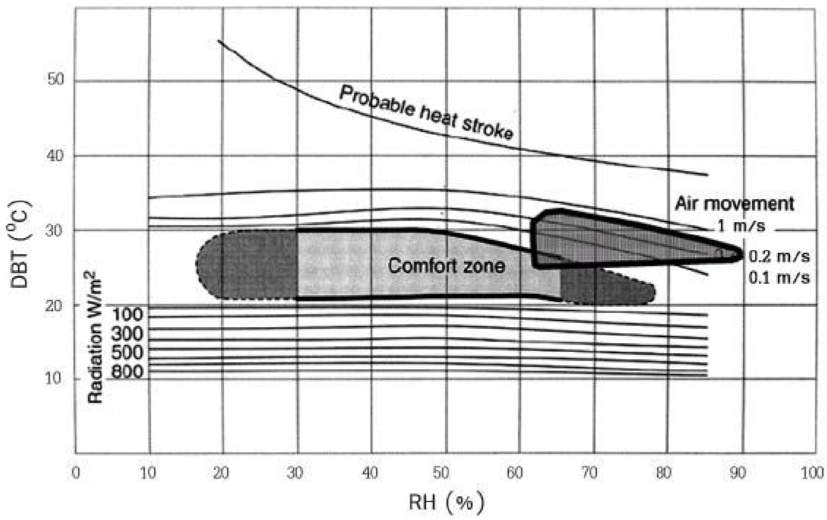


Fig. 2.8 : Olgyay's bioclimatic chart modified for hot humid climates. The new comfort zone is shown on the right of the original one
Source : (Chenvidyakarn, 2007)

2.3.2 Principles of energy efficient building design

According to Majumda (2002) the design principles of energy efficient buildings can be categorized into four sections planning principles, building envelope and fenestration principles, passive cooling techniques and passive heating techniques.

2.3.3 Planning principles:

Planning principles study the macro and microclimate of the site to avoid the adverse conditions, and taking advantage of the desirable conditions:

1. Building form/surface-to-volume ratio

Building form is one of the most important principles due to the fact that it determines the amount of heat loss or heat gain through the building envelope. Building form can be defined by the shape factor (the ratio of building length to building depth), height and roof type. As shown in fig. (2.9), there is possible to determine a lot of building forms that have same volume, but different facade area. Thus, The ratio of total facade area to building volume (A/V) is the best indicator describing the building form (Oral, 2003). Also, the building form determines the airflow pattern around the building, and affect its ventilation. Additionally, The depth of a building determines the requirements for artificial lighting, so the greater depth needs more artificial lighting (Majumda, 2002).

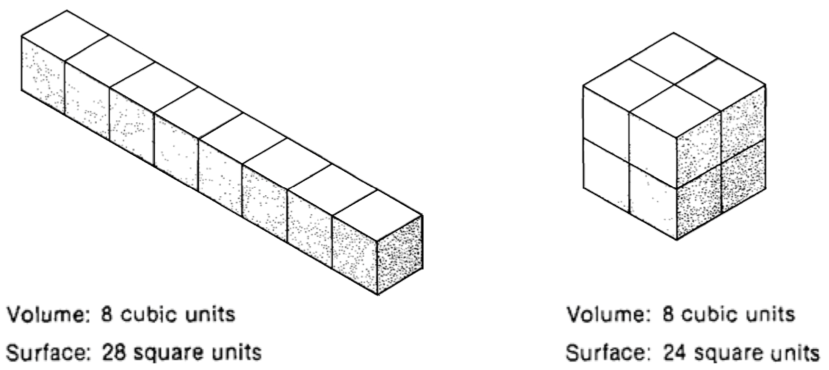


Fig. 2.9 : Surface-to-volume ratio
Source : (Bradshaw, 2006)

2. Orientation

Building orientation is an important design consideration, mainly with regard to solar radiation and wind. In hot humid climates, buildings should be oriented to minimize thermal impact from solar radiation and maximize effectiveness of ventilation. This can be achieved by lying the longer axis of building along east-west direction, as shown in fig. (2.10) . That because the longer sides of the buildings should face the prevailing winds (north direction) and the shorter sides should face the direction of the strongest solar radiation (east and west directions) (Mathur, 2003).

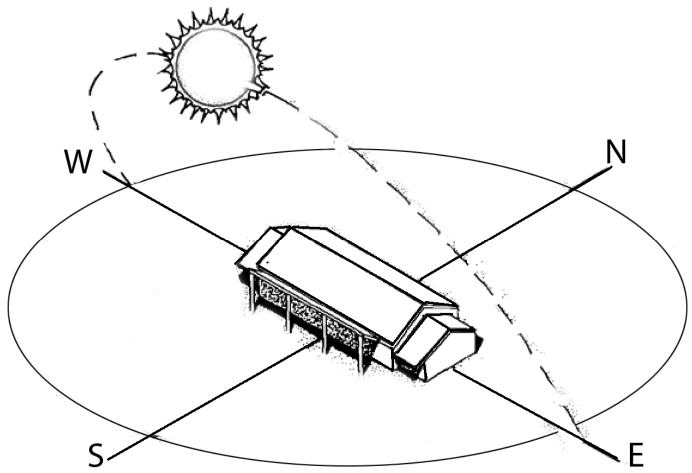


Fig. 2.10 : The best orientation of the building to solar radiation and wind
Source : (Bradshaw, 2006)

3. Vegetation

Vegetation can play an important role of reducing the temperature around the buildings. It can reduce the solar heat gains on windows, walls and roof through shading. Ground cover by plants also reduces the reflected solar radiation and long-wave radiation emitted towards the building. In hot humid climates, the adverse effects from increased humidity due to the evapotranspiration process should be taken into consideration, especially when plants are grown near ventilation inlets (Chenvidyakarn, 2007). According to Giridharan (2008) there are four characteristics of vegetation affect both indoor and outdoor thermal conditions in any location which are density of plants, types of plants, size and shape of trees and shrubs, and locations of plants, trees, etc.

2.3.3 Building envelope and fenestration principles

The building envelope and its components determine the amount of heat gain and heat loss and wind that enters inside. The basic elements of building envelope and its effects are discussed below:

1. Materials and construction techniques

According to Majumda (2002) selecting the building materials is essential in reduction the demand of energy. Thermal insulation which is one of materials properties can effectively reduce the space conditioning loads. It needs a careful study of its location and thickness. For example, in hot climates, insulation should be located on the outer face of the wall to separate the external hot temperature. Also the external finish of a surface determines the amount of heat absorbed or reflected by it. For example, a smooth and light colour surface reflects more light and heat than a dark colour surface.

2. Roof

The roof receives large amount of solar radiation which causes large heat gain and heat loss. Thus, it is required treatments according to climatic characteristics. For example, in a hot region, the roof should have enough insulation to minimize heat loss. In addition, the roof can be used for useful ventilation and daylighting by added vents and skylights (Majumda, 2002).

3. Fenestration and shading

All the elements in the building envelope, windows and others glazed areas are the weakest link between the building and outdoor. The most important design parameters affecting the thermal performance of windows are orientation, glass, size and shading device. All of these parameters will be discussed in more details in the next chapter (Majumda, 2002).

4. Natural ventilation

Natural ventilation is one of the requirements for low-energy building design. It is the use of wind pressure and stack effect as a natural forces to move the air through buildings. These effects are different according to the strength of the prevailing wind and the temperature conditions.

The effect of wind pressure is a very complex process. It mainly depends on the principle that air always flow from a region of high pressure to a region of lower pressure. In the light of this principle there are many factors affecting natural airflow in and around buildings.

Briefly, the outdoor factors include suction and wind flow around buildings, the shape and orientation of the building relative to the direction of the wind, effects of coastal areas and effects of vegetation. Inside the building, the main factors affecting the pattern of airflow entering a building are opening size and shape, opening location, opening types and vertical and horizontal projections (Busato, 2003). According to (Omer, 2008) the most widely used methods in natural ventilation is classified into three types, see fig. (2.11).

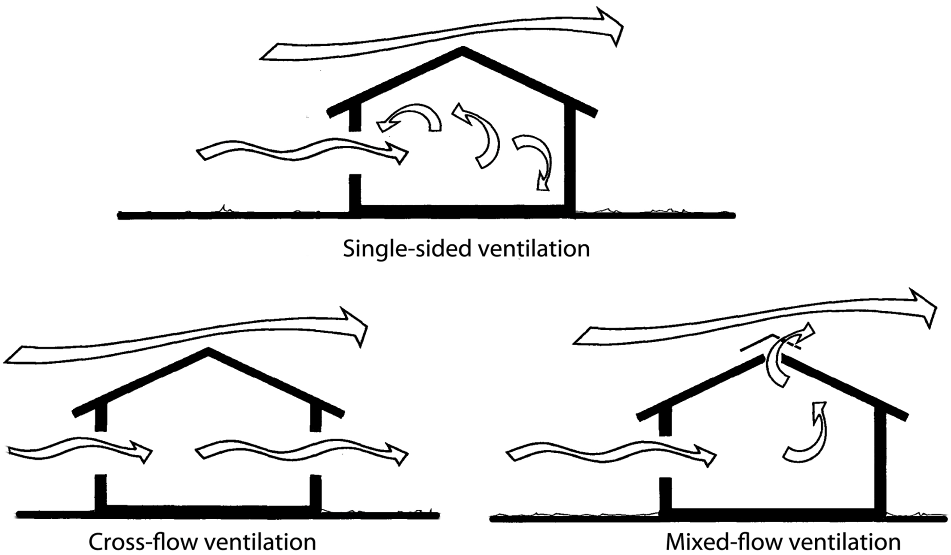


Fig. 2.11 :The most common methods used in natural ventilation

Source : (Baker, 1978)

The stack effects are caused by temperature differences between the inside and outside of buildings. When the inside building temperature is greater than the outside, a warm air in building rises to escape through upper openings, and it is replaced by cooler outside air enter through low openings around the building. As shown in fig. (2.12), to increase the effectiveness of this system the sun can be used to create a solar thermal chimney to increase the air flow by increasing the temperature differences (Khan, 2008).

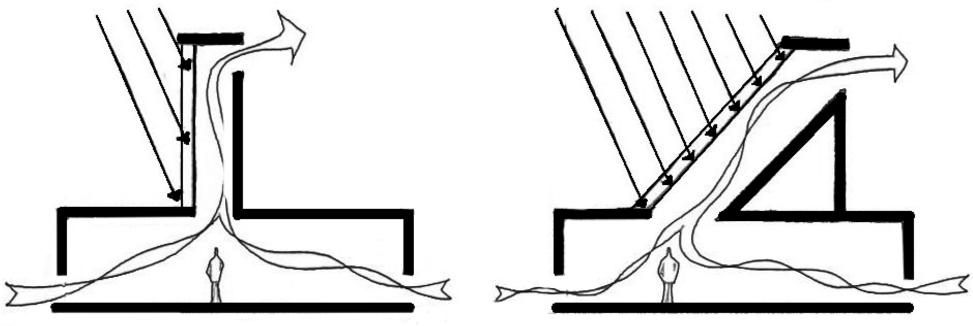


Fig. 2.12 : The vertical and inclined solar chimney
Source : (Moore, 1993)

5. Daylighting

Daylight integration is an important aspect of energy-efficient building design. It can bring a sense of well being and awareness of the wider environment. According to Majumda (2002) Many factors should be taken into consideration to achieve good daylighting system in building:

- Orientation, space organization, and geometry of the space to be light.
- Location form, and dimensions of the fenestrations to allow entering of daylight.
- Location and surface properties of internal partitions that affect daylight distribution by reflection.
- Location, form, and dimensions of shading devices that provide protection from excessive light and glare.
- The Light and thermal characteristics of the glazing materials

2.3.5 Passive cooling techniques

This section briefly discuss the passive techniques that aid heat loss from the building by ventilation, radiation, and evaporation, or by using storage capacity of surrounding spaces like mass effect (Moore, 1993).

1. Passive cooling by ventilation

According to Moore (1993) the Concept of passive cooling by ventilation depends on replacement of warmer inside air with cooler outside air at various rates (5 to 500 air changes per hour). In arid climates, night-only ventilation has been generally used. This takes advantages of the cool night air temperatures while isolating the interior from the extremely hot daytime condition.

2. Passive cooling by radiation

Radiative cooling is the transfer of heat from a warmer surfaces of buildings to cooler surrounding surfaces. The following discuss the performance of some radiative systems such as courtyards, roof pond, and cool pool.

Courtyards is considered one of the radiative cooling systems when its surfaces are exposed to the night sky. The radiation of these surfaces can be increased by designing the roof surrounding the courtyard to be sloped toward the courtyard, as fig. (2.13) shows (Moore, 1993).

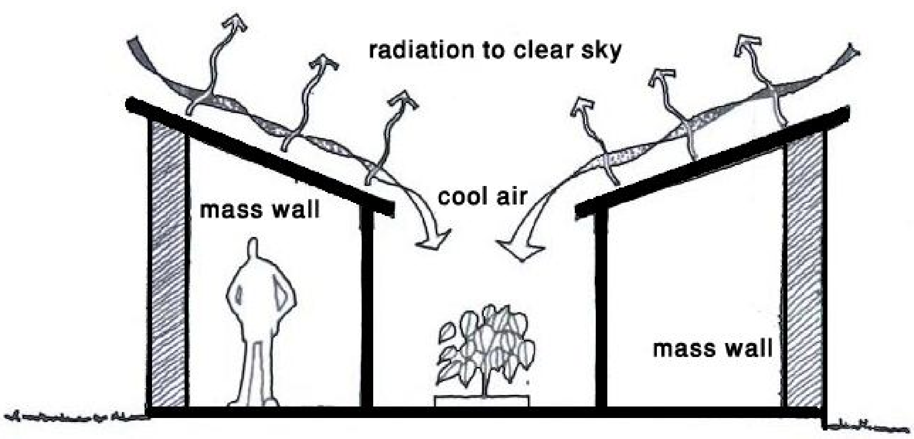


Fig. 2.13 : Courtyard as a radiative cooling system
Source : (Moore, 1993)

The roof pond system also provides summer passive solar cooling, see fig. (2.14). During a day, the water pond is covered by the insulating panels to reduce solar heat gain and to absorb internal heat, At night, the pond are uncovered and it radiates storage heat to outside.

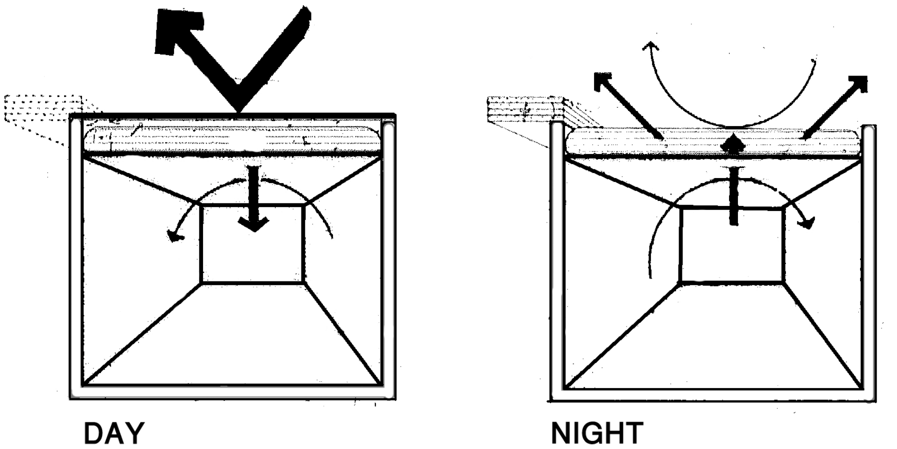


Fig. 2.14 : The roof pond as a radiative cooling system
Source : (Mazria, 1979)

The cool pool is a passive roof-cooling system. As shown in fig. (2.15), the pool is cooled by radiation to the sky. Then the cooled water is piped to a large water storage tube inside the building below. So a thermal circulation occurs when the roof pool is cooler than storage tube (Moore, 1993).

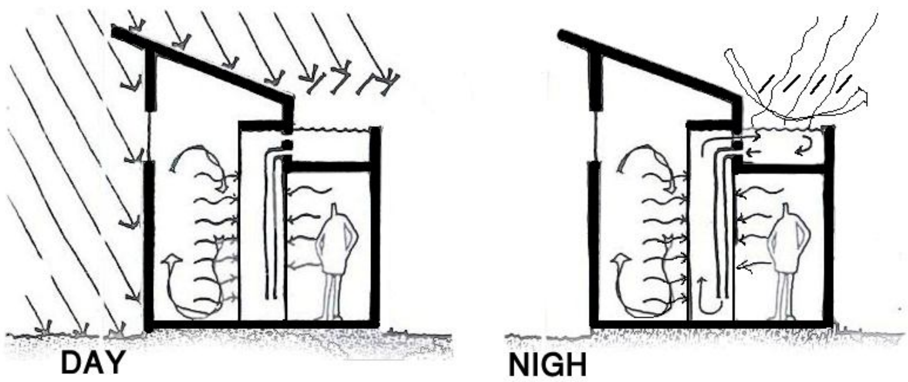


Fig. 2.15 : The cool pool as a radiative cooling system
Source : (Moore, 1993)

3. Passive cooling by evaporation

According to Moore (1993) Evaporation cooling is the process of extracting sensible heat from the air while adding an equal amount of latent heat (in the form of water vapor), the total heat remains the same. As shown in fig. (2.16), there are two methods to cool building air either directly by evaporation or indirectly by contact with a surface previously cooled by evaporation.

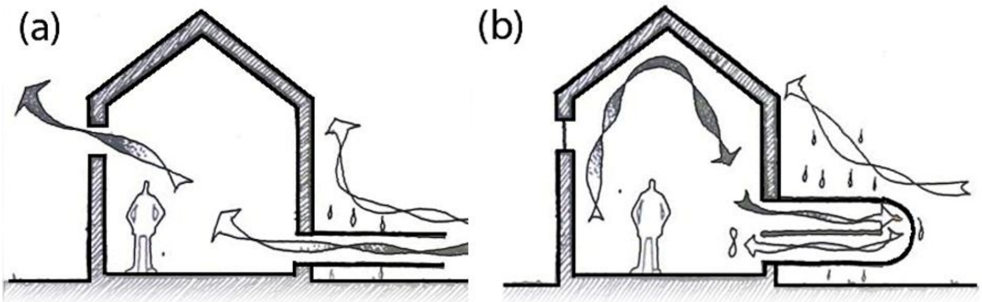


Fig. 2.16 : Indirect evaporative air coolers: (a) open-loop, and (b) closed-loop
Source : (Moore, 1993)

4. Passive cooling by mass effect

Buildings with substantial mass can utilize their thermal storage capabilities to achieve cooling in three ways. First, dampening out interior daily temperature swings, by using interior building materials for walls and floors of conductive and massive construction, they gradually absorb and release heat. Second, delaying temperature extremes, by using building materials for walls and floors also of conductive and massive construction, there is a significant time delay (time lag). Third, earth contact to achieve seasonal storage, by using the earth ability of heat storage for seasonal storage purposes (Moore, 1993).

There are two basic strategies for using earth contact: direct and indirect contact. In the direct contact, the building envelope is partially or completely buried underground. While indirect contact, the building is cooled by buried heat exchangers such as pipes or air tubes.

2.3.6 Passive heating techniques

Passive heating techniques are used by architects in building design to achieve thermal comfort conditions in cold climate. There are two basic elements in every passive solar-heating system. First element is the south-facing glass (or transport plastic) for solar collection. Second element is the thermal mass for heat absorption, storage and distribution (Mazria, 1979).

Generally, passive solar heating systems can be classified into direct gain systems ,indirect gain systems and isolated gain system:

1. Direct gain system

According to Mazria (1979) in the direct gain approach the actual living space is used as a solar collector and directly heated by sunlight, as shown in fig. (2.17). It contains a method for absorbing and storing enough daytimes heat for cold winter night. In this approach there is an expanses of south-facing glass and enough thermal mass, straightly located in space, for heat absorption and storage. The two most common materials used for heat storage are masonry and water.

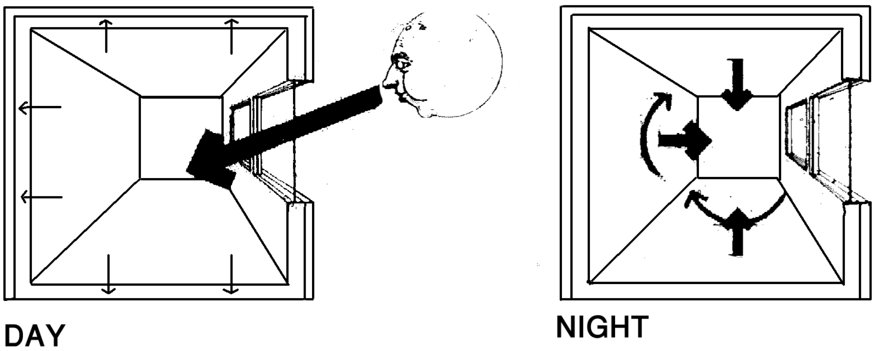


Fig. 2.17 : Direct gain system – masonry heat storage
Source : (Mazria, 1979)

2. Indirect gain system

In this system, the sunlight first strikes the thermal mass which is located between the sun and the space. The sunlight absorbed by the mass is converted to thermal energy (heat) and then transferred into the living space. There are basically three types of indirect gain systems:

The first system is thermal storage walls system . It uses either masonry or water walls to collect and distribute heat to space. Only one difference between two types, a water transfers this heat through the wall by convection, while masonry by conduction, see fig. (2.18) (Mazria, 1979).

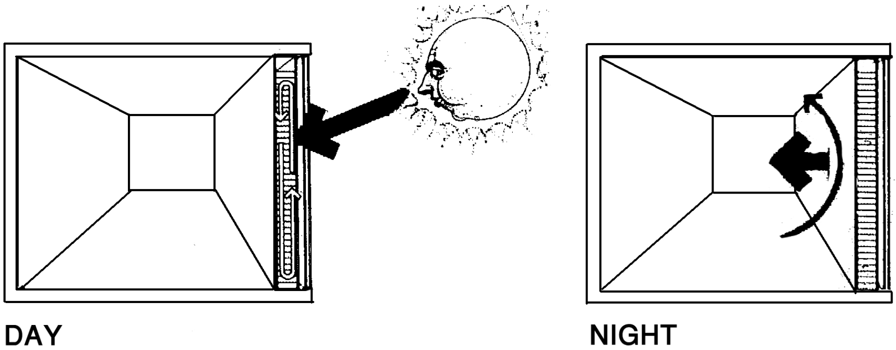


Fig. 2.18 : Indirect gain – water thermal storage wall
Source : (Mazria, 1979)

The second system is attached sunspace. As shown in fig. (2.19), it is essentially a combination of direct and indirect gain systems. Basically, sun light is absorbed by the back wall in the sunspace, converted to heat, and a portion of this heat then transferred into the building (Mazria, 1979).

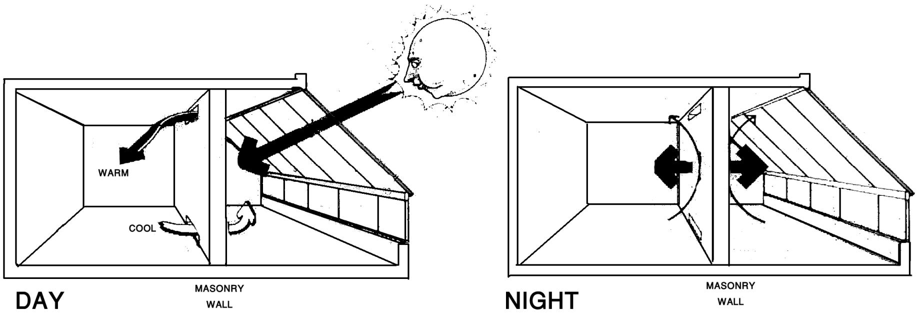


Fig. 2.19 : Indirect gain – attached sunspace
Source : (Mazria, 1979)

The third system is the roof pond. As shown in fig. (2.20), in this system, the thermal mass is located on the roof of the building.

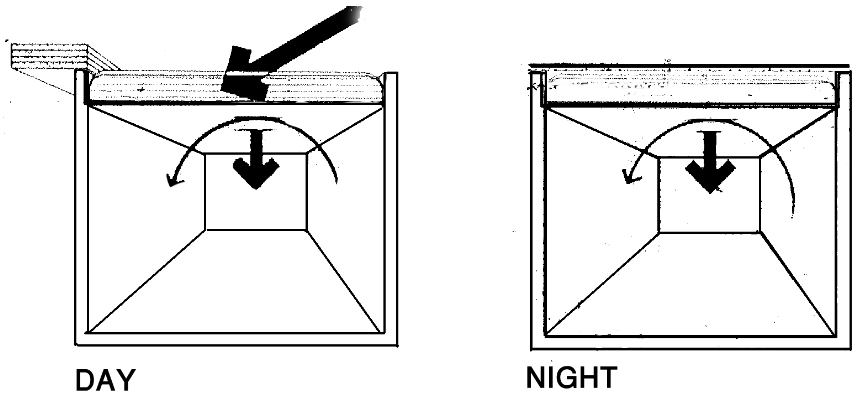


Fig. 2.20 : Indirect gain – roof pond
Source : (Mazria, 1979)

3. Isolated gain system

In this system, solar collection and thermal storage are isolated from the living spaces. The most common application of this concept is the natural convective loop, see fig. (2.21). The major components of this system include a flat plate collector and heat storage tank. Two types of heat transfer and storage mediums are used: water and air with rock storage (Mazria, 1979).

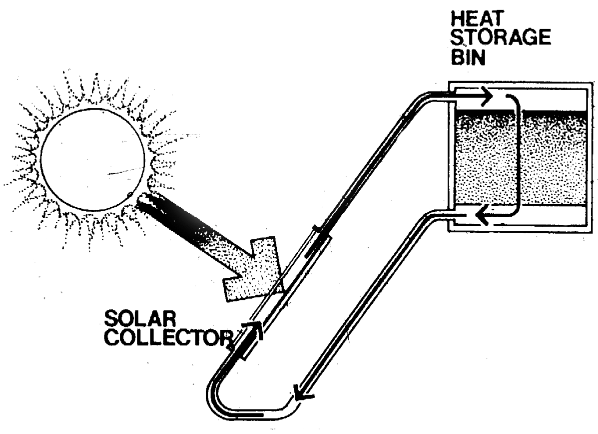


Fig. 2.21 : Convective loop
Source : (Mazria, 1979)

Conclusion

This chapter investigated the energy situation in the world and its rate of consumption. The conclusion emphasized that the world energy requirements increases steadily and the reliance is mainly on the fossil resources which causes harmful environmental impacts. However, the clean and renewable energy sources are considered the reliable alternatives.

The chapter also presented the energy situation in the Gaza Strip. It is clear that the Gaza Strip is suffering from many problems related to energy as that there is almost no conventional sources except the recent exploration of the gas field near the Gaza strip beach. In addition, there is a shortage of electricity supply estimated by 25%.

The buildings sector are considered the large consumer of energy. Thus, many principles to design low energy buildings are also discussed in this chapter including planning, building envelope, passive cooling and passive heating. It has been concluded that these principles can easily integrated into building design and can contribute effectively to reduce the energy consumption.

Chapter

3

Energy-Efficient Window Design

Introduction

As mentioned in the previous chapter, windows are an important envelope element as they play many functions in the building. These functions include supplying of daylight, providing outside views, acting as part of natural ventilation system. In addition, windows can play important role in architectural appearance of the building. This chapter focuses mainly on investigating the design principles of windows which can contribute to reduce the energy consumption. Among several factors, transmitt0 solar radiation directly into the indoor spaces through windows is considered the main factor that affect the thermal state of building. Therefore, controlling the penetration of solar radiation through windows is an essential requirement to achieve energy-efficient window design. According to Ingersoll (1979) there are four factors for controlling the solar heat gain. These factors that include window size, orientation, thermal properties of glass material, and shading devices will be discussed in more detail in the this chapter.

3.1. Definition and function of window

Before going into the details of the principles of energy efficient window design, it is necessary to give an introduction about windows to understand its definition, components, properties, functions and types.

3.1.1 Window definition

According to Jonsson (2010) window is an opening in a wall, roof or door to allow passage of light and air. The origin of the word window is from Norwegian “vindauga”, from ‘vind - wind’ and ‘auga - eye’.

The good window design provides several functions which are allowing visible light, giving an outside view, acting as heat and sound insulation and also function as part of the ventilation system. In addition, windows can play essential function in architectural appearance of the building (Jonsson ,2010).

From the history point of view, the first “windows” were just holes in the wall. Then the holes were covered with cloth, wood or animal hide. nowadays, glass is the common material used in windows. It made out of molten silica, a special kind of sand, that is carefully cooled without crystallizing. It has been known before 4,000 years when stone-age man uses cutting tools made of natural glass, but it is used in windows about 2,000 ago (Persson, 2006).

3.1.2 Window Components

window components include glazing material, framing, external and internal shading devices, and integral (between glass) shading systems. These components with more details are illustrated below and in fig. (3.1). In the front view in figure (3.1) it is clear that the window is basically divided into three components: frame, edge and glazed zone (Gustavsen, 2001).

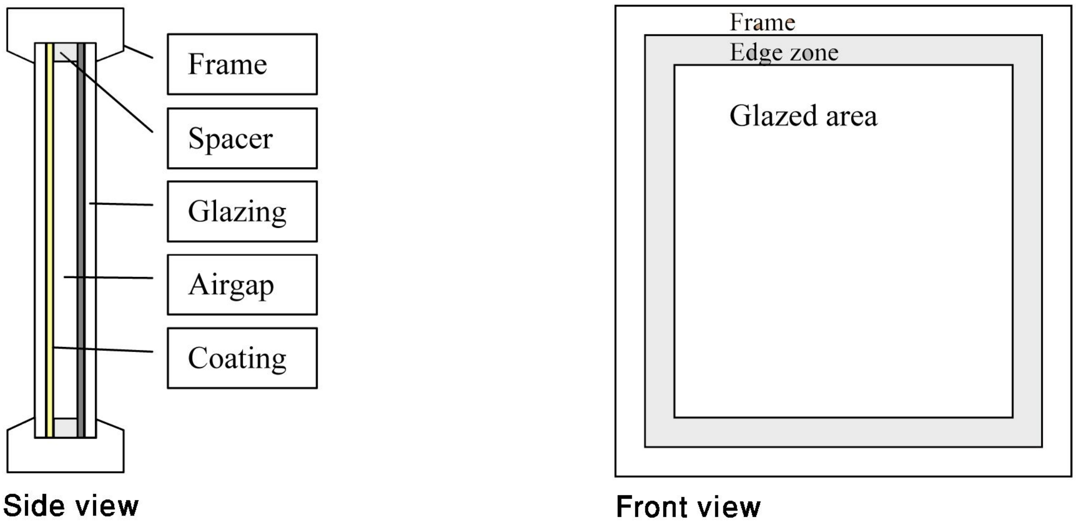


Fig. 3.1 : Components of window
Source : (Karlsson, 2001)

1. Frame

The frame is a border which forms the perimeter of a window. It can also be defined as the parts of window surrounding the glazing. the thermal performance of window frame is usually specified by the U-factor (thermal transmittance). There are different types of frames like aluminum, wooden and PVC frame with steel reinforcement (Gustavsen, 2001).

2. Glazing

The glazing is mainly the larger part of a window. Its main function is to allow visible light and prevent passage of air or other elements (Gustavsen, 2001). There are several types of advanced glazing such as low-emitting glazing (low-e) that are used to reduce the thermal losses, and solar control glazing that are used to reduce the cooling load (Karlsson et al., 2001).

3.1.3 Properties of window

In general, the properties of window can be divided into optical and thermal aspects. it is necessary to introduce few information about these aspects to be able to distinguish the different types and functions of windows.

1. Optical properties

The optical properties of a window describes the interaction between glazing and electromagnetic radiation. The electromagnetic radiation reaching a glass is classified into three types some of the light is reflected, some is transmitted, and some is absorbed in the glass. This is illustrated in fig. (3.2). The absorbed light is transformed to heat and then emitted to the inside and the outside as radiation (Persson, 2006).

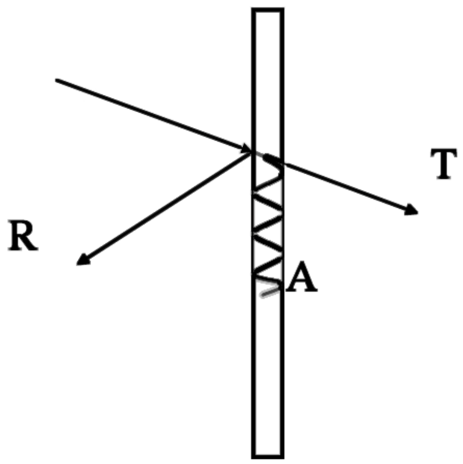


Fig. 3.2 : Light transmitted (T), reflected (R) and absorbed (A) by a glass pane
Source : (Persson, 2006)

2. Thermal properties

The heat transfer through a window occurred in three different ways: radiation, convection and conduction. Radiation is the thermal radiation exchange between surfaces and surroundings. Convection is the transported heat from the surface by air movements. Conduction is the transfered heat by the thermal motion of atoms and molecules (Jonsson, 2010)

3.1.4 Functions of window

Windows play many functions such as supplying daylight, providing views of the outside, act as part of ventilation for air quality and cooling purpose, and act as a noise and heat insulator and glare protector. They also have an important impact on the energy efficiency of a building (Jackson, 1999).

This thesis focuses on the function of windows in the thermal performance of a building. This will be investigated by discussion some parameters that play major role in determining the amount of heat gain and heat loss between buildings and the environment

3.1.5 Types of window

The windows can be classified into various types such as fixed windows, openable windows, roof windows, aluminum windows, wood windows, etc. For example, according to their operating system, windows can be categorized into slider, double hang, casement, awing and hopper type, as shown in fig. (3.3) (Gustavsen, 2001).

Also windows can be categorized according to the type of glazing like Low-e windows, solar control windows and smart windows. These types will be discussed in more description in the section of glazing (Jonsson, 2010).

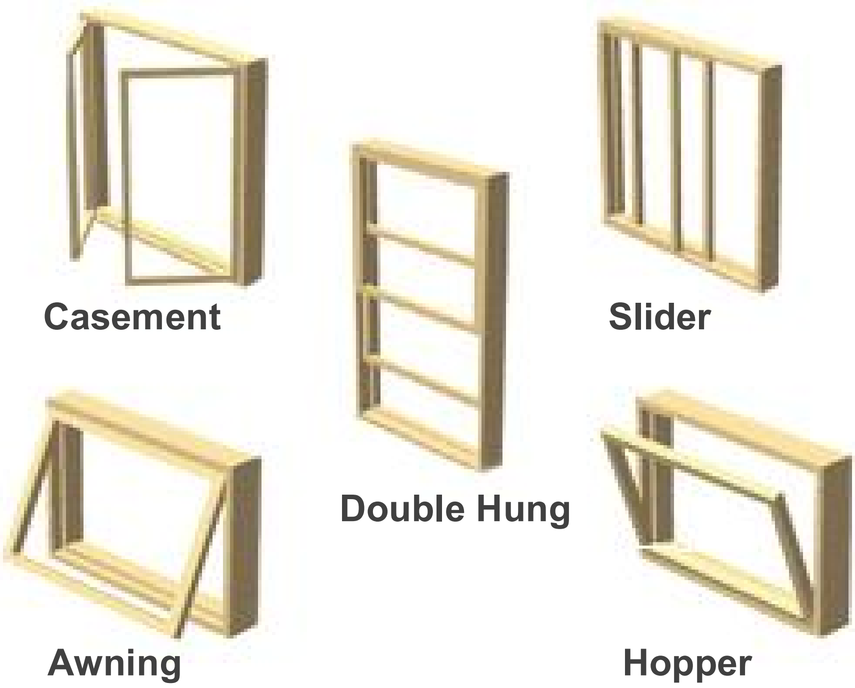


Fig. 3.3 : Types of window according to the operating system
Source : (Gustavsen, 2007)

3.2. Principles of energy efficient window design

There are many aspects should be taken into consideration when selecting the effective windows in buildings. Some of these factors are shown in fig. (3.4) such as the amount of light they allow, the amount of flowing heat radiation and the aesthetic appearance (Persson, 2006). As mentioned before, this thesis will focus only on the thermal performance aspect of the windows.

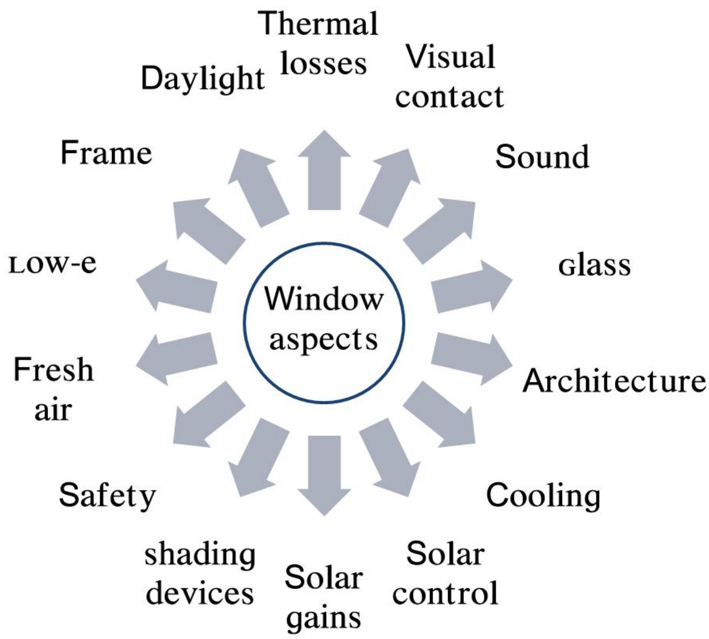


Fig. 3.4 : Several window aspects
Source : (Persson, 2006)

The thermal performance of a window can be basically specified by three factors the thermal transmittance (U-value), total solar energy transmittance (g-value), and air leakage (L). These three factors describe all amount heat flow through a window (Urbikain, 2009). The U-value of the window is the heat transfer rate per temperature difference between the inside and the outside of the window per square meter and it is measured by the unit of ($W/m^2.k$). The g-value is the total solar energy transmittance through window, it is also called the solar heat gain coefficient, and it is measured from 0 to 1 unit (Werner, 2007). Finally, Air leakage increases the thermal performance of a building by the incoming air which may heat or cool the indoor air temperature (Urbikain, 2009).

The solar gain entering through a window represents the largest source of heat gain, hence increase the indoor temperature above the outdoor air temperature. This increasing occurs through greenhouse effect when the radiant heat is trapped inside the building by window glasses (Ingersoll, 1979). Windows also are responsible for about 25-30% of the heat loss in a building because window glazing is a poor insulator. Thus, windows play important effect on the heating and cooling requirements, energy costs and the thermal comfort level of occupants (Halder, 2007).

In other words, windows are the weakest link in a building envelope for heat gain in the summer and heat loss in the winter. This gain or loss through windows changes from one day to another throughout the year and also depends on the climate where the window is used, the type of building and the orientation. As example, during summer, the highest solar gain occurs on eastern and western facades in the early morning and late afternoon while the lowest solar gain occurs on northern facade. For the southern facade, the solar gain is decreased at low latitude and it is increased at high latitude. Thus, the window design should change from one facade to another (Ingersoll, 1979).

Based on the previous facts, control the penetration of solar radiation through windows is an essential requirement for preventing the increase of heat gain or heat loss. According to Ingersoll (1979), there are four factors for control the solar gain entering through windows which are:

- Window size
- Orientation
- Thermal properties of glass material
- Shading devices

These four factors are explained in more detail in the following pages.

3.3. Window size

Window to wall area ratio (WWR) is one of the most important factors affects the energy consumption of buildings. According to Ahsan (2009), inlet and outlet windows should be large enough on opposite walls for effective cross-ventilation in tropical climates. Although increasing the window to wall ratios (WWR) can improve the ventilation and indoor air quality, it will also increase solar heat gain. Beside these two factors, daylight provision also should be taken into account when selecting the optimum window to wall area ratio.

According to Ahsan (2009) Liping et al. (2007) carried out a study to determine the indoor thermal environment of naturally ventilated buildings in the hot-humid climate of Singapore by using building simulation and indoor CFD (computational fluid dynamics) simulation. The window size which investigated in this study is modified from WWR= 0.1 to WWR= 0.4 for all orientations. The results show that the optimum window to wall ratio is equal to 0.24 for the optimum natural ventilation. Beside these results, the horizontal shading devices are recommended for the four orientations, particularly for large windows.

3.4. Orientation

Window orientation to right directions play important role not only in reducing energy consumption but also in thermal comfort. In hot and humid regions, the orientation of windows should aim to minimize solar penetration. At the same time, windows should be oriented toward the prevailing wind for the purpose of natural ventilation (Ahsan, 2009).

The orientation of window is important because large windows facing wrong directions cause more heat gain during the summer and more heat loss during the winter (Geun, 1997). The amount of daily solar radiation received by north and south facades is less than received by east and west facades. Thus, from the heat gain point of view, east and west direction are the worst orientations and window should be avoided as possible in these facades (Mathur, 2003). On the other hand, from the architecture point of view, architects prefer to design big window to make the building attractive. They believe facades with less window may make them boring and solid walls. This problem can be solved by using verandahs and roof overhangs to shade it (Ahsan, 2009).

3.5. Thermal properties of Glass material

The essential functions of glazed windows are to let natural light into the building, to allow a view of the outdoors, as well as to make the appearance of buildings look more aesthetic. In hot and humid region, besides the advantages of the glass windows as described above, the glass windows act as a means to admit solar radiation into buildings and convert it into building heat gain and then building cooling load (Chaiyapinunt, 2005).

Solar radiation reaching glass surface can be divided into three types reflected, absorbed and transmitted. The percentage of the radiation that will be reflected, absorbed or transmitted depends on following factors:

- The nature of the glass itself.
- The thickness of glass, surface coating.
- The number of glass layers used.

According to Kasule (2003) the percentage of solar radiation that will reach the indoor space depends on the following factors:

- Type of glass used (thickness, coating and filling).
- The incident angle of the incoming sun rays: transmission through glass decreases with increase in incident angle, while reflection by glass increases with increasing angle of incidence.
- The area of the glass.
- The orientation of glass on the building.

A main energy-efficiency strategy to reduce heat gain through window is the development of advanced glazing materials with low U-factor (thermal transmittance). This can be investigated either by modification the properties of the glass itself, or by adding a coating to the surface of the material (Etzion, 2000).

There are many type of advanced windows such as Low-e, solar control and smart windows. Low-emitting (low-e) window is a window coated with a thin film layer that exhibits low thermal emittance and high solar transmittance and it is used to reduce the thermal losses. A solar control window is also coated with a thin film layer that exhibits low solar transmittance and it is used to reduce the cooling load (Karlsson, 2001). Smart window is used to change the daylight transmittance between a light and a dark state (Jonsson, 2010).

Airflow windows are also considered one of the recent technologies. Its advantage is not only improve indoor air quality but also conserving energy in buildings and enhance daylighting. There are four main types of airflow windows: supply, exhaust, indoor air curtain and outdoor air curtain as shown in Fig. (3.5). In each window, the outside is the left side and the inside is the right side (Gosselin, 2008).

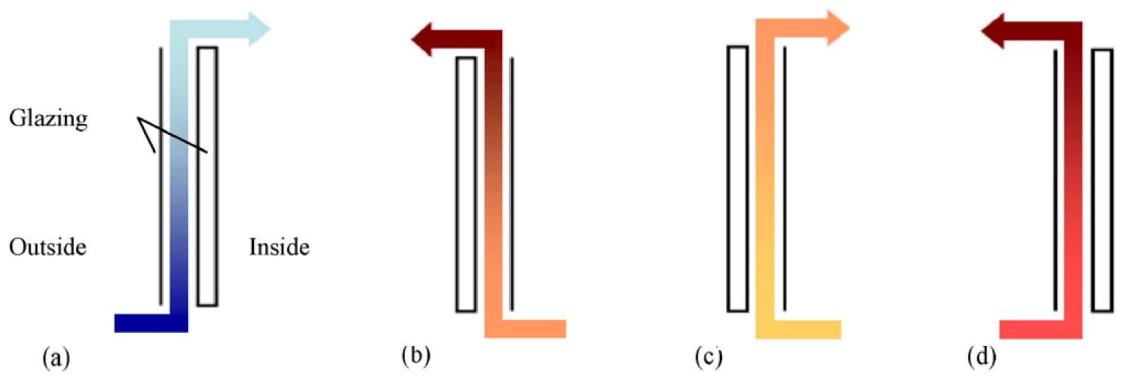


Fig. 3.5 : Airflow window types: (a) supply, (b) exhaust, (c) indoor air curtain and (d) outdoor air curtain

Source (Gosselin, 2008)

3.6. Shading devices

Shading devices can play important role in control the solar radiation that enter into the room especially during summer months. Shading devices can control solar radiation in three ways. First, they protects from sunlight. Second, they redirects the solar radiation and softens the excessive solar energy. Third, they diffuses the light and gives visual comfort (Geun, 1997). According to Dubois (2000), the appropriate design of shading devices can effectively reduce cooling load. This reduction ranges between 23-89% depending on the type of shading device used, the building orientation, the climate, etc.

Shading devices differ in their characteristics and dimensions according to the duration of sunshine on the window facade. For examples, south windows can easily be shaded during summer because of the high position of the sun in the sky and they can be designed to accept high solar heat gains during winter. In contrast, there are some difficult in shading of west and east windows because of the low position of the sun in the sky. North windows also accept very limited solar heat gains, restricted to the summer early morning and late afternoon hours, so shading may be not necessary in the north façade (Vogel, 2004).

The functions of shading systems are to improve thermal and visual comfort by reducing overheating and glare, and to provide privacy (McKay, 2010). In some cases the disadvantage of shading devices is that it may reduce availability of daylight which enter the building, hence increasing consumption of energy for artificial lighting. Thus, an effective shading device should be able to prevent the unwanted solar heat and allow the needed daylight to reach the building interior (Mathur, 2003). Shading devices should be able to perform some of these functions:

- Stop solar radiation penetration into the building during hot periods.
- Allow solar radiation penetration into the building during cool periods.
- Should allow view to the outside from inside the building.

- Should allow daylight into the building.
- Provide some privacy whenever required.
- Protect the occupants of the building from glare.
- Should not interfere with air circulation through the windows.

Although adjustable shading devices may respond to multi demands than fixed ones, it is difficult for a shading device to effectively perform all previous functions. Thus, a device should be chosen after identifying its functions (Kasule, 2003).

Generally, solar radiation entering a room through windows can cause three effects: increase in air temperature by radiation absorbed on room surfaces, increase in the mean radiant temperature of occupants, and the third important effect is that high intensities of radiation from direct sun can cause discomfort glare. The performance of shading devices is measured by the level of reduction in negative impacts of these three effects (Baker, 1987). The following section discuss in details the performance parameters of the shading devices.

3.6.1 Performance parameters for shading advices

Performance parameters for the shading devices include: thermal, visual, acoustic and aesthetic performance. The values of these parameters depend on the independent variables such as climate, site, and building type, and dependent variables, such as heat transfer, facade type, and position of the blinds relative to the window (Olbina, 2005).

1. Thermal performance

There are three parameters determine the thermal performance of the shading device: protection from overheating in summer by reflection or absorption, protection from heat loss in winter, and collection of sun energy. In hot climates, shading device systems should protect the interior space from overheating in summer. The thermal performance can also be measured by the level of protection from heat loss during winter nights in cold climates. Another parameter is the collection of solar energy by absorbing instead of reflecting which can be used in many applications like the building's mechanical systems.

2. Visual performance

Visual performance of the shading device includes: providing sufficient illuminance, providing sufficient luminance, protection from glare, providing privacy, providing desired darkening of the interior space, and providing direct visual contact to the outside space. The building type affects the previous visual performance parameters. For example, providing privacy and darkening of the space is desirable in residential buildings, but not necessarily in office buildings.

3. Acoustic performance

Acoustic performance parameters of the shading device include: sound transmission and vibration of the blinds. Both building location and site affect the acoustic performance of the shading device. For example, a higher level of noise occurs in urban areas requires selecting a specific shading device to reduce this noise. The blinds installed outside can vibrate because of wind, resulting in increased noise level. Thus, they should be fixed carefully to avoid the problem of vibration (Olbina, 2005).

4. Aesthetic performance

The shading device is an important architectural element. It has a significant impact on both the exterior and interior appearance of the facade. Aesthetic performance parameters of the shading device include: blinds' transparency, blinds' translucency, and percent of window area obstructed by the blinds. There is a strong relationship between the aesthetic performance parameters and thermal, visual, and acoustic performance. For example, the blinds' transparency and percent of window area obstructed by the blinds depend on the requirements for the protection from overheating and the desired daylight level in the interior space (Olbina, 2005).

3.6.2 Different shading device types

There are many different kinds and categories of shading devices. It can be classified into three main types fixed overhang shades, louvers, and movable shades as illustrated in fig. (3.6). According to the position of a shading device relative to the building envelope, shading devices can be divided into internal and external devices. The external devices also can be divided into the sub categories of vertical, horizontal and combined devices. In addition, vegetation element is considered as a important type of shading devices (Baker, 1987). All these types of shading devices and its main characteristics will be discussed in the following sections.

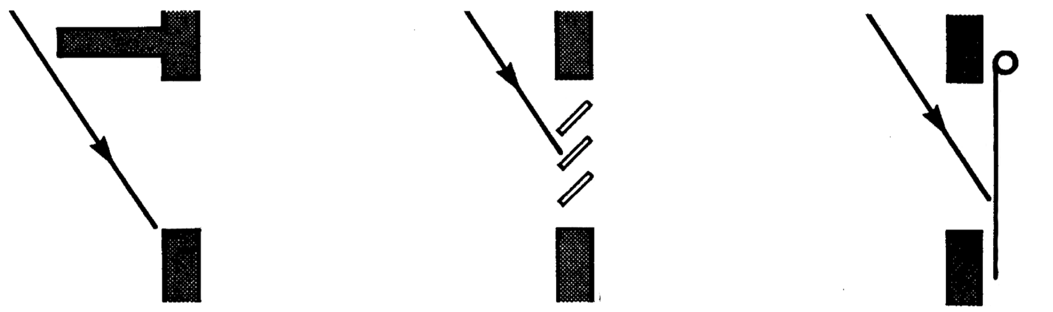


Fig. 3.6 : Classification of shading devices
Source : (Baker, 1987)

1. Fixed devices

Fixed shading devices are parts of the building or extra structures mounted on the building facade. They can be external or internal structures, however they usually used in the outside of building envelope. There are many types of fixed shading devices such as horizontal overhangs, vertical fins, combination of horizontal and vertical elements, balconies or internal elements like louvers and light-shelves. The most significant advantage of fixed shading devices is that they are "passive" or self-operating. In addition, fixed devices are preferred because of their simplicity, low maintenance cost and sometimes low construction cost (Vogel, 2004).

Particularly, fixed shading devices are effective at preventing direct sun radiation, but it less effective against diffuse or reflected radiation. The horizontal overhang is the most common form of fixed shading device. It can effectively be used on the south-facing facade to provide complete shading during summer and allow solar penetration in winter. However, Fixed horizontal devices do not generally provide effective protection from the low-angled sunlight of morning and afternoon, particularly on the east and west facades (McKay, 2010).

2. Movable devices

Moveable devices can be located externally, internally or between the panes of a double or triple glazed window. They can be external shading elements in the form of tents, awnings, blinds, pergolas, or internal elements like curtains, rollers and venetian blinds. Movable devices are more flexible because they can modify according to the dynamic nature of the sun's movement (McKay, 2010). The concept of moveable devices depends on changing the cut-off angle to match the changing solar altitude as a result of the movement of the sun. These devices can be operated manually or automatically (Kasule, 2003).

Both colour and material influence the effectiveness of shading system. According to Vogel (2004), the white venetian blinds give 20% shade protection more than dark ones, while for roller blinds the effect can reach 40%. An aluminium blind can add 10% more protection than a coloured one. For internal curtains the differences are less, as light coloured ones are only 18% more effective than dark ones. Fig. (3.7) shows shaded performance of various materials. Part of the sunlight will be reflected out through the glazing and the rest of the solar energy will be absorbed, convected and re-radiated into the room. Thus, It is not possible to achieve 100% efficiency in the shading system. In the light of the previous fact, the dark coloured in internal shading devices should be avoided (Vogel, 2004).

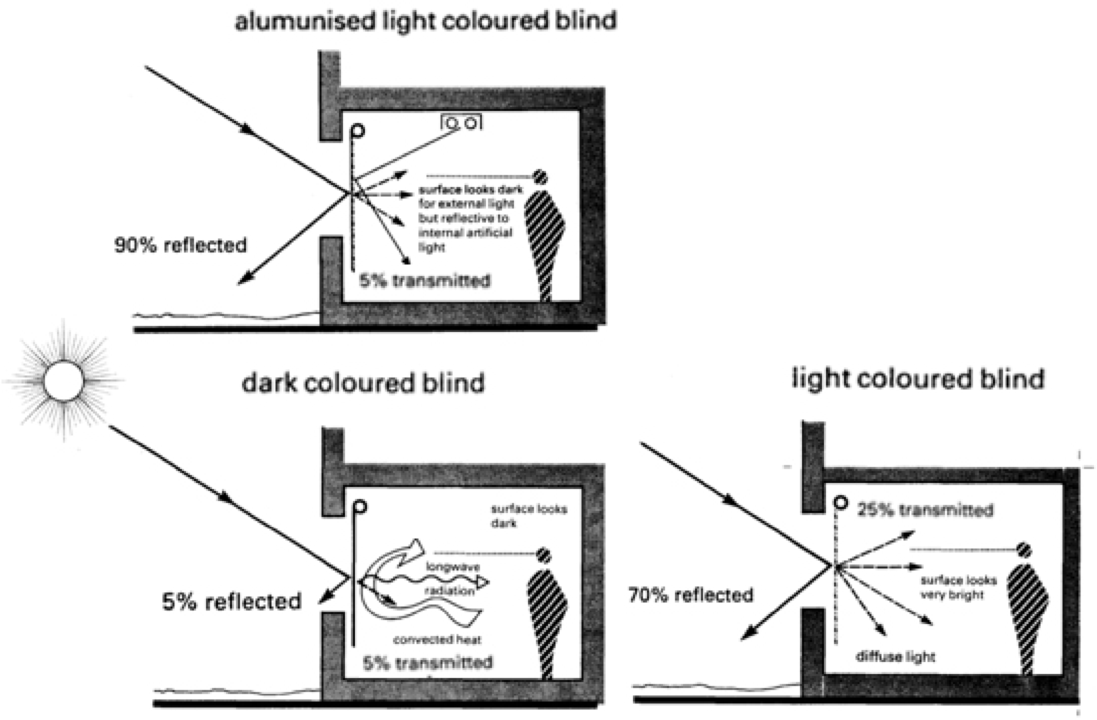


Fig. 3.7 : Performance of various materials
Source : (Baker, 1987)

3. Internal devices

Internal shading devices are that mounted on the inner side of the building envelope. They can either be fixed like interior light shelves or adjustable like louvers, curtains, etc. Fig. (3.8) shows the difference between interior and external shading devices. It demonstrates that internal shading devices are considered less effective than external ones because the sunlight enters the building envelope. In contrast, external shading devices diffuse any absorbed solar energy to the outside air. Thus, the efficiency of external shading devices increases about 30% over internal shading devices, but internal devices are considered cheaper and easier to operate manually (Vogel, 2004)..

Kasule (2003) studied the influence of the position of a shading device on room temperature by carrying out comparison between building with a device installed outside the building envelope (external device) and one installed inside the building (internal device). The results shows that external shading devices are the best. When replace an interior shading device by an exterior device under similar conditions, the reduction in the room temperature is down about 10°C below that of a room without shading device.

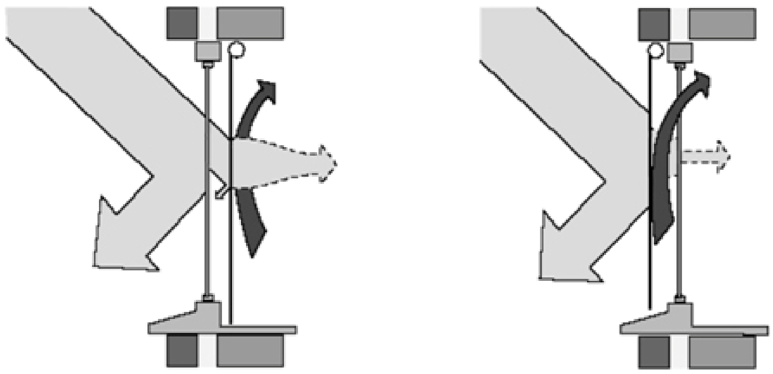


Fig. 3.8 : The difference between internal and external shading devices
Source : (John, 2004)

4. External devices

External shading devices are that mounted on the outer side of the building envelope. Their main function is to trap solar radiation before it reaches the building envelope. External shading devices can play important role in architectural appearance of the building facade. Thus, their colour, form, and shape should be selected carefully during the design phase (Kasule, 2003).

According to Ingersoll (1974) external shading devices can be divided basically into three categories which are horizontal shades, vertical shades, and compound shades. The vertical devices will be most effective when the sun is opposite to the wall considered, such as an eastern or western facade. The performance of vertical devices can be measured by a horizontal shadow angle. Table (3.1) shows many forms of vertical shading devices.

In contrast, The horizontal devices will be most effective when the sun is opposite to the building face considered and at a high angle, such as for north and south facing walls. The performance of horizontal devices can be measured by a vertical shadow angle (Ingersoll,1974). Some forms of horizontal shading devices is shown in Table (3.2).

The last one of external devices, the compound devices, are combination of horizontal and vertical elements. This type of device can be effective for any orientation depending on detail dimensions (Ingersoll,1974). Some types of compound shading devices is shown in Table (3.3).

Table 3.1 : Vertical shading devices

Source: : (Ministry of Local Government, 2004)

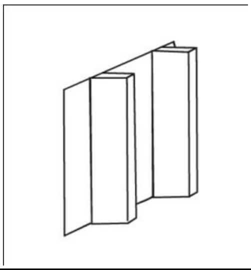
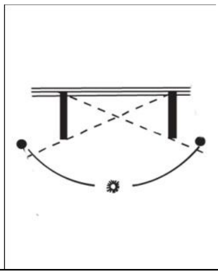
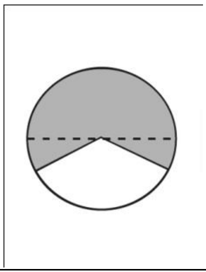
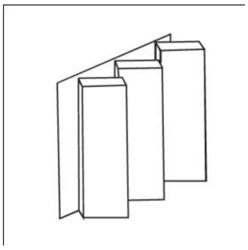
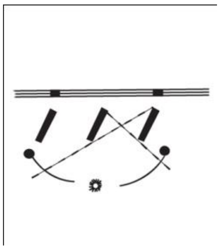
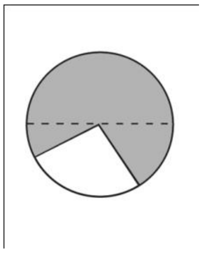
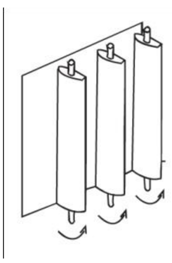
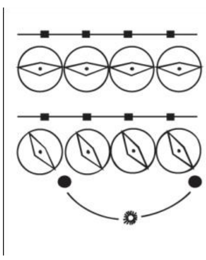
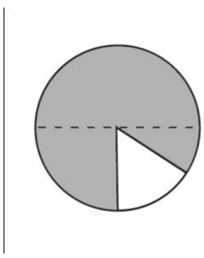
Shading Device	Plan View	Shading Mask	Comments
			**Vertical fins** are most effective on the near-east, near-west and north exposures.
			**Slanted vertical fins** are most effective on east and west exposures. Slant toward north and separation from wall minimizes heat transmission.
			**Rotating vertical fins** are the most flexible and adjustable for daily and seasonal conditions. Most effective on east and west exposures.

Table 3.1 : Horizontal shading devices

Source: (Ministry of Local Government, 2004)

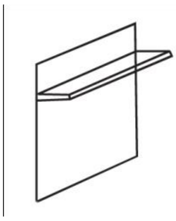
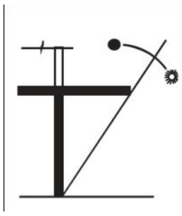
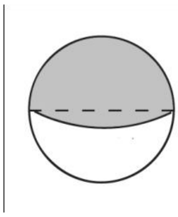
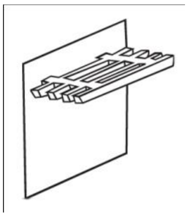
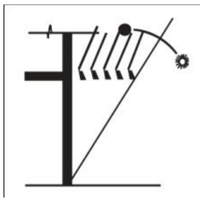
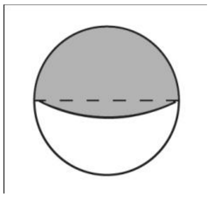
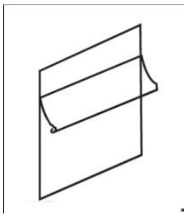
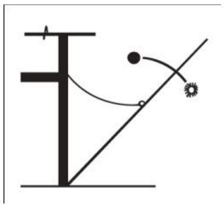
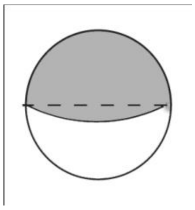
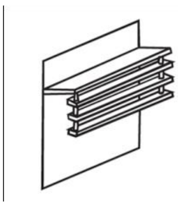
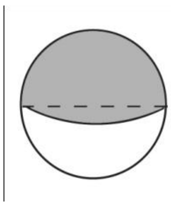
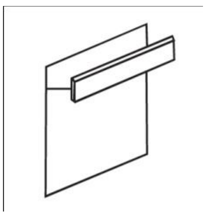
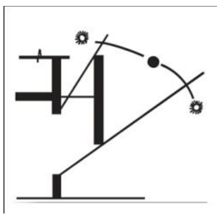
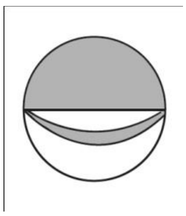
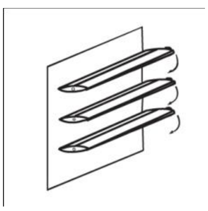
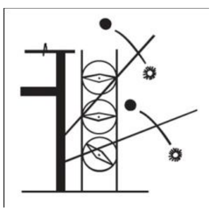
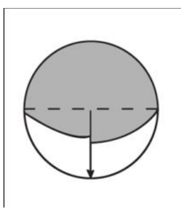
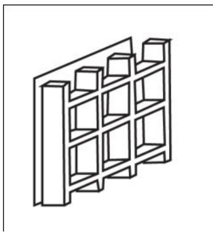
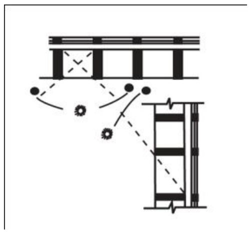
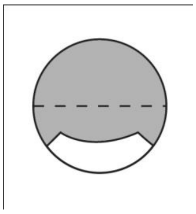
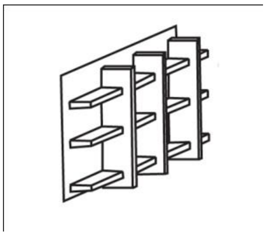
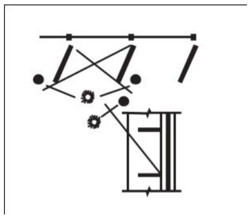
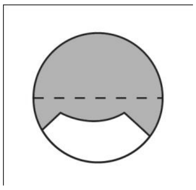
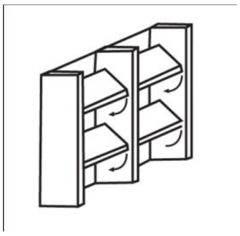
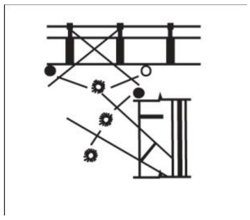
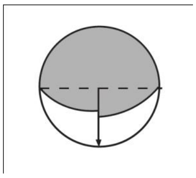
Shading Device	Side View	Shading Mask	Comments
			**Straight overhangs** are most effective on southern exposure.
			**Louvers parallel to wall** allows hot air to escape and are most effective on southern exposure.
			**Awnings** are fully adjustable for seasonal conditions and most effective on southern exposure.
			**Horizontal louvers hung from solid overhangs** cuts out the lower rays of the sun. Effective on south, east and west exposures.
			**Vertical strip** parallel to wall cuts out the lower rays of the sun. Effective on south, east and west exposures.
			**Rotating horizontal louvers** are adjustable for daily and seasonal conditions. Effective on south, east and west exposures.

Table 3.1 : Combined shading devices

Source: (Ministry of Local Government, 2004)

Shading Device	Plan & Side View	Shading Mask	Comments
			**Compound types** are combinations of horizontal and vertical types. Most effective in hot climates on east and west exposures.
			**Compound with slanted vertical fins** (slant toward north). Most effective in hot climates on east and west exposures.
			**Compound with rotating horizontal louvers**. Most effective in hot climates on east and west exposures.

5. Vegetation devices

Vegetation around a building can play a significant role in shading system. It modifies the thermal properties of the surrounding air and improves the microclimate around the building so it is better than artificial shading device. It can be in the form of trees, bushes, pergolas, trellis, etc (Vogel, 2004). The effectiveness of vegetation for shading depends on the position, orientation, type and the shape of selected plant. During selecting the appropriate vegetation, the attention should be given to avoid obstructing prevailing winds which is useful for natural cooling. The advantage of some trees shed their leaves in winter can be used effectively to allow solar radiation to reach the building in winter while benefit from its shading in summer (Kasule, 2003).

3.6.3 Design of shading advices

The sun is considered as a main source of unwanted heat gain in buildings. To understand the techniques of reduction solar gain through windows by shading devices, there is a need to understand the geometrical relationship between the earth and the sun, and the physical properties of solar radiation.

1. Solar geometry

This section discuss the movement of the sun (the solar geometry) and its relationship with the earth.

- **The earth and the sun**

The earth moves around its own axis once every twenty-four hours. It rotates around the sun once every year. As shown in fig. (3.9), the earth's movement around the sun follows an elliptical path. The distance between earth and sun changes slightly. At its maximum the earth–sun distance is 152 million km and at its minimum 147 million km (Szokolay, 2004).

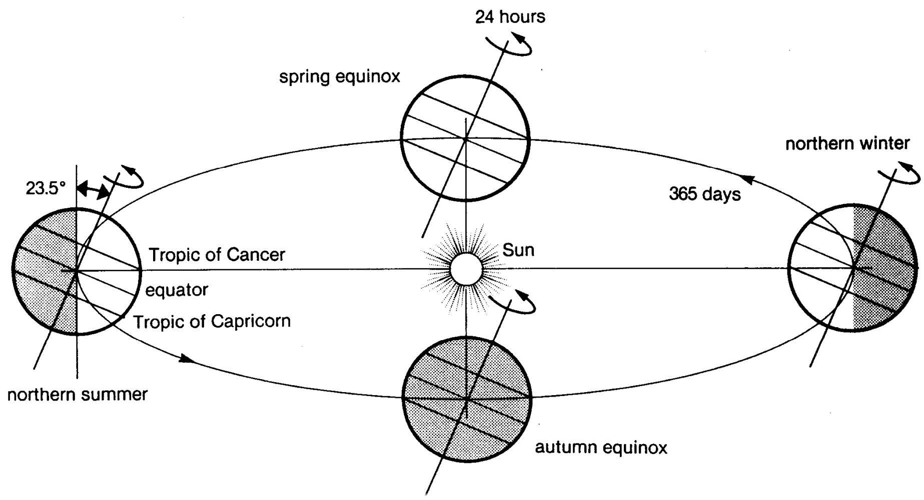


Fig. 3.9 : Sun-earth movement
Source : (Baker, 1987)

The earth's axis of rotation is titled at 23.5° to the plane of the earth's rotation around the sun. The tilt angle of the earth is the cause of the seasons, not the distance from the sun. This because the tilt allows the sun's rays to shine more directly and for longer periods of time in some locations at certain times of the year than others (Vogel, 2004). As shown in fig. (3.10), the north pole is tilted toward the sun in summer and away from the sun in winter.

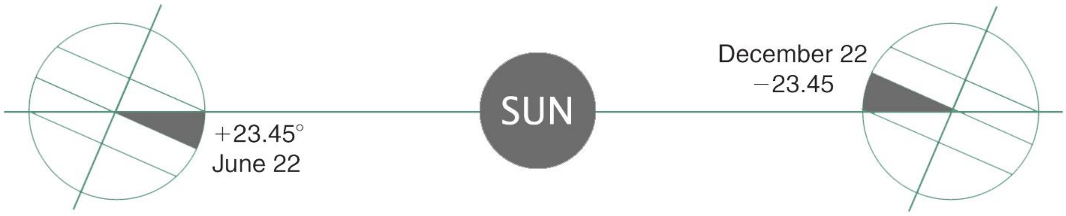


Fig. 3.10 : Two-dimension section of the earth's orbit
Source : (Szokolay, 2004)

From our viewpoint here on earth, in the northern hemisphere, this means that the sun is higher in the sky in summer, and lower in winter. Consequently, the amount of solar radiation striking the earth is less during the winter, because the sun's rays need a greater distance to travel through the atmosphere in winter, and they strike the earth's surface at a lower angle (Anderson, 1987). During the summer months, the situation is reversed, the northern hemisphere receives more hours of sunshine and the sun's rays strike the earth's surface at almost perpendicular angle (Vogel, 2004).

- **The sun's position**

A knowledge of the sun's position helps in determination of the effective orientation of a house and placement of windows to collect the most winter sunlight. This knowledge is also helpful in designing shading devices and vegetation to block the summer sun (Anderson, 1987). The position of the sun in the sky can be specified by two angles. First, solar altitude angle (α), which is the vertical angle between the horizon plane and the line connecting the sun with the observer and it ranges from 0° (horizontal) to 90° (vertical). Second, solar azimuth angle (γ), which is the horizontal angle between the northerly direction and a point on the horizon circle and it ranges from 0° to 360° clockwise from the north. These angles are illustrated in fig. (3.11) (Ingersoll, 1974).

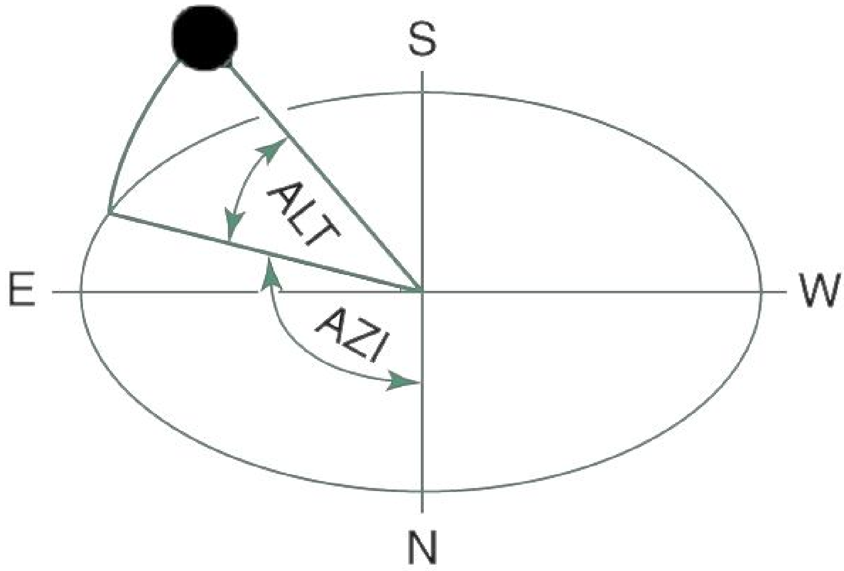


Fig. 3.11 : Altitude and azimuth angles
Source : (Szokolay, 2004)

These sun's position angles can be read directly for any date of the year and any hours of the day from the solar chart or sun path diagrams. There are several methods for representing the 3D suns apparent movement on a 2D circular diagram. The stereographic method of projection is the commonly used. It projects a view of the sky onto a horizontal plane. As an example, a complete sun-path diagram for latitude 36° is given in fig. (3.12). Radiating lines indicate azimuth and the concentric circles show angular altitude. A group of curves extending from east to west presents the suns path at various dates. These date lines are intersected by the short hour lines (Ingersoll, 1974).

As an example, the following describe the process to find the sun position in latitude of 36° at 15:00 hours on 22 December: See fig. (3.12).

A. Selecting the chart of latitude 36°.
B. Selecting the 22 December data line.
C. Selecting the 15:00 hour line and determine its intersection with data line.

D. The concentric circle passing through intersection time point is the altitude angle. (in this example it = 18°)

E. Connecting straight line from the centre of the chart through the intersection time point to the perimeter scale and read the azimuth angle. (in this example it = 223°) , (Ingersoll, 1974).

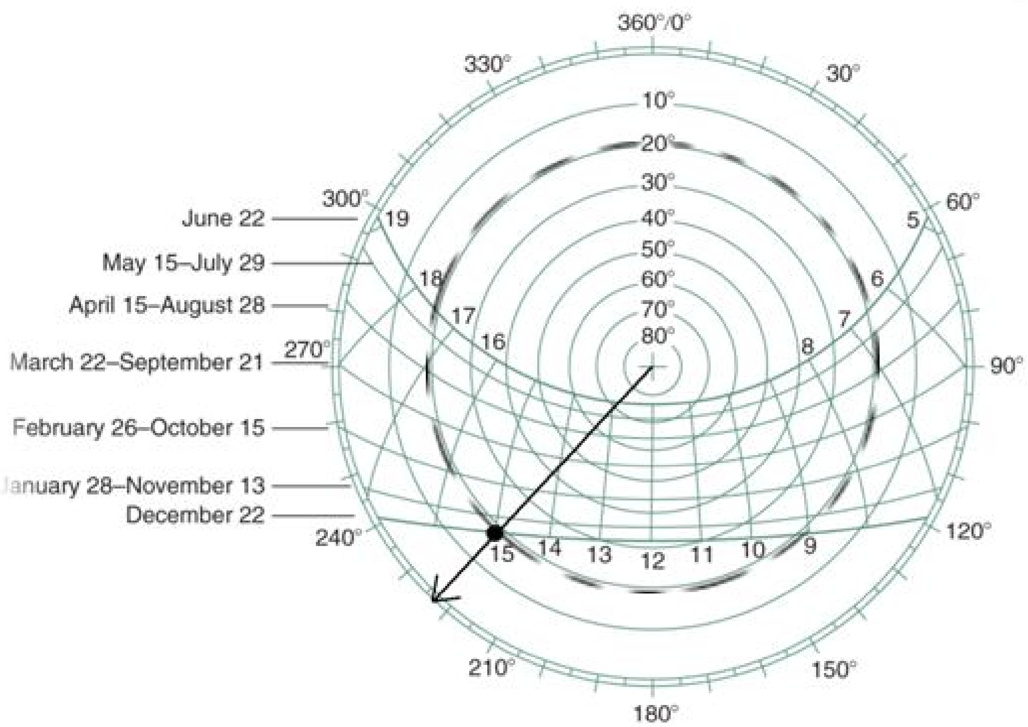


Fig. 3.12 : A Stereographic sun-path diagram for Latitude 36°

Source : (Szokolay, 2004)

- **Solar time and local time**

During the earth moves around the sun, its speed changes according to its distance from the sun. Due to the variation of the earth's speed in its revolution around the sun there is difference between sun and earth time (Vogel, 2004). The time used on solar charts to describe the position of the sun in the sky are based on the solar time (ST) not on the local (clock) time (LT). This solar time coincides with local clock time only at the reference longitude of each time zone. The 360^0 circumference of the earth, in terms of time, represents 24 hours. One hour equals 15^0 longitude (360/24 = 15), or 4 minutes equals 1^0 longitude (60/15 = 4 min) (Szokolay, 2004). It is important to understand the difference to determine actual position of the sun in the sky at a particular moment based on altitude and azimuth. This difference between solar time and local clock time can be corrected by applying three conversions which are the correction needed if daylight saving time is used, a constant correction based on the four minutes that the sun takes to cross 1° longitude, and the third correction for effect of the earth's elliptical orbit around the sun and the inclination of the earth's axis on the ecliptic plane) (Vogel, 2004).

2. Solar radiation

The solar radiation, which also called global solar radiation, is divided into three different components: the direct-beam component, the sky-diffuse component and the reflected diffuse component (reflected from the ground and the surroundings).

Direct radiation refers to the solar radiation arrives the earth's surface by passing straight through the atmosphere without any scattering in its way through the atmosphere. Diffuse solar radiation also refers to the solar radiation which is scattered by moisture vapour and small airborne particles. In addition, reflected solar radiation describes the incident solar radiation which is reflected back into space from clouds and atmospheric dust, and some reflection occurs at the surface of the earth such as water, snow and sand) (Vogel, 2004).

The amount of solar radiation reaching the earth's surface varies depending on three factors. First, angle of incidence: according to the cosine law the radiation received by a surface is the normal radiation multiplied by the cosine of the incidence angle. Second, factor of variations in cloud cover and atmospheric pollution. Third, the duration of sunshine: the solar radiation during summer is excepted to be more than during winter because the length of daylight hours) (Szokolay, 2004).

As fig. (3.13) shows, about 31% of solar radiation reaching the earth's surface is reflected, while the remaining 69% enters the terrestrial system. Part of this energy is absorbed by the atmosphere before reaching the ground and around 50% reaches the ground surface. This proportion is not fixed but varies according to the atmospheric conditions) (Szokolay, 2004).

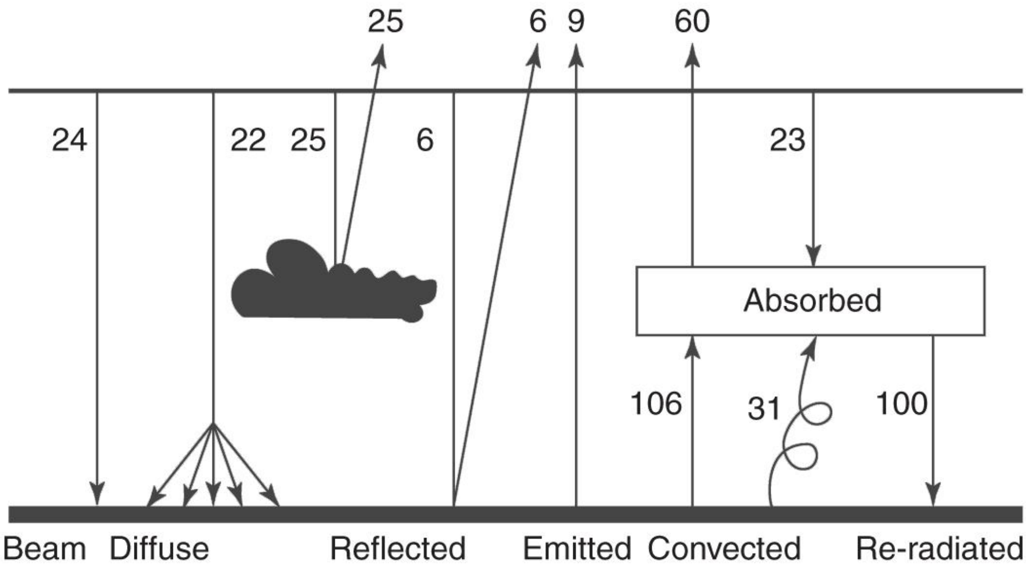


Fig. 3.13 : Radiation balance in the atmosphere
Source : (Szokolay, 2004)

3. Shadow angles

Shadow angles express the sun's position in relation to a building face and can be used to specify the shadow produced by shading device. As shown in fig. (3.14), There are two shadow angles the horizontal and the vertical angle:

- **Horizontal shadow angle (HSA):** describes the performance of a vertical shading device, and it is the difference in azimuth between the sun's position and the orientation of the building wall, (HSA = AZI – ORI). HSA is measured from the direction of orientation (from the surface normal), positive in clockwise and negative in the anticlockwise direction. The HSA cannot be greater than (90°) or less than (-90°) (Ingersoll, 1974).

- **Vertical Shadow Angle (VSA)**: describes the performance of a horizontal shading device, and it is measured on a plane perpendicular to the building face. The different between solar altitude angle and the vertical shadow angle is that the first describes the sun's position in relation to the horizon, and the second describes the shadow produced by shading device. The VSA can exist only when the HSA is between (-90^o) and (+90^o). The VSA equals ALT only when the sun is directly opposite the wall and when HSA equals (0^o) (Ingersoll, 1974).

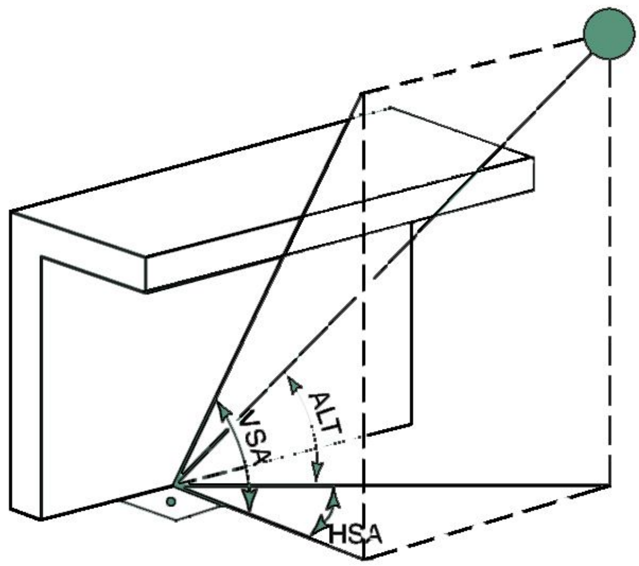


Fig. 3.14 : Definition of shadow angles

Source : (Szokolay, 2004)

4. Shadow angle protractor

The HSA and VSA values can be specified on a solar protractor. The performance of a shading device is described by a shading mask, which can be also specified by the shadow-angle protractor. As shown in fig. (3.15), The shadow angle protractor is a semi-circular protractor showing two types of lines which are arcual and radial lines:

- **Radial lines** ,marked 0 at the centre, to -90^o to the left and +90^o to the right, gives HSA values.
- **Arcual lines** gives VSA values.

The solar protractor is then located over the latitude sun-path diagram to read dates and hours of shading. The effective device should be selected based on its shading mask of which covers the overheated period (Szokolay, 2007).

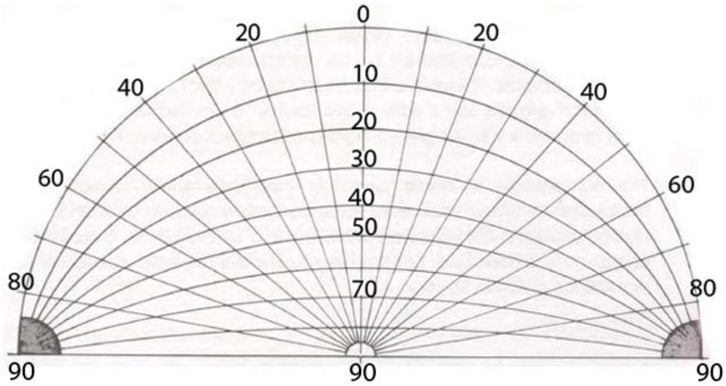


Fig. 3.15 : The shadow-angle protractor
Source : (Szokolay, 2007)

As mentioned above, the vertical devices are characterized by horizontal shadow angles (HSA). Fig (3.16) shows a pair of vertical devices in plan. The line connecting the edge of the device and the opposite corner of the window gives the shading line. The angle between this line and the device is the HSA angle. Also fig (3.16) shows that the shading mask takes a sectoral shape. This shading mask, when superimposed on the sun-path diagram according to the orientation of the building, will cover the time when the window will be in shade, as shown in fig. (3.20) (Szokolay, 2004).

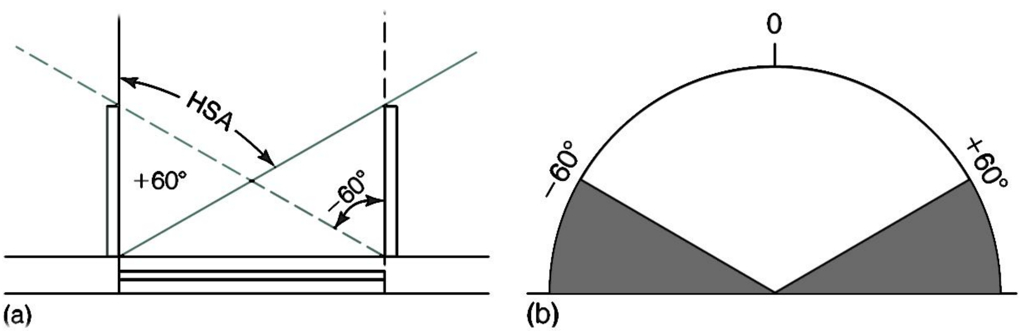


Fig. 3.16 : Plan of a pair of vertical devices and their shading mask
Source : (Szokolay, 2004)

The following fig. (3.17) shows many combinations of vertical elements with the same HSA can give the same shading performance (Szokolay, 2007).

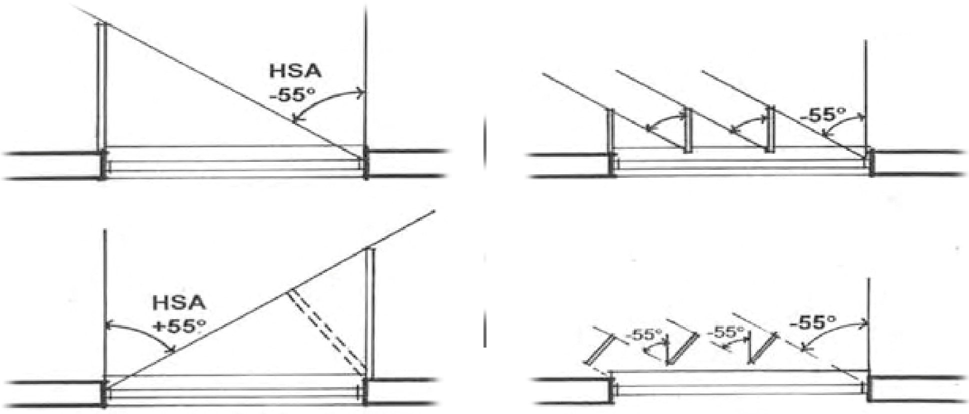


Fig. 3.17 : Vertical devices with the same HSA giving similar performance
Source : (Szokolay, 2007)

In contrast, the horizontal devices are characterized by vertical shadow angles (VSA). Fig (3.18) shows the section of a window vertical devices. The line connecting the edge of the device and the opposite corner of the window gives the shading line. The angle between this line and the horizontal is the VSA of the device. Also fig (3.18) shows that the shading mask takes a segmental shape. This shading mask, when superimposed on the sun-path diagram according to the orientation of the building, will cover the time when the device is effective, as shown in Fig. (3.20) (Szokolay, 2004).

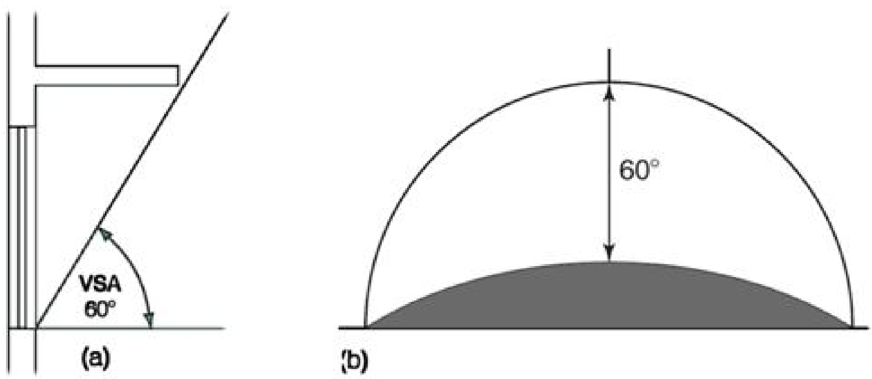


Fig. 3.18 : The section of a window vertical devices and their shading mask
Source : (Szokolay, 2004)

The next fig. (3.19) shows many combinations of horizontal elements with the same VSA can give the same shading performance (Szokolay, 2007).

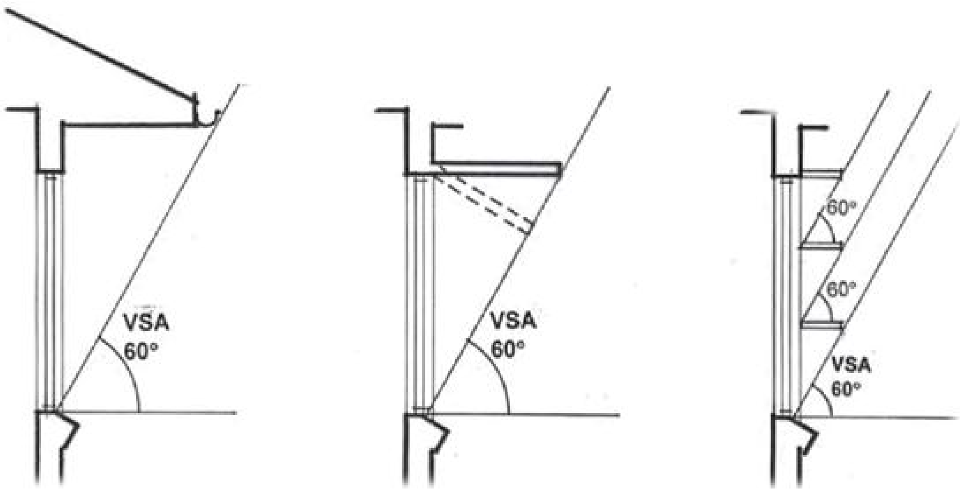


Fig. 3.19 : Horizontal devices with the same VSA giving similar performance
Source : (Szokolay, 2007)

The last one is the compound devices which also call egg-crate devices. They produce complex shading masks. they are combinations of the above two devices, and cannot be characterized by a single angle) (Szokolay, 2004).

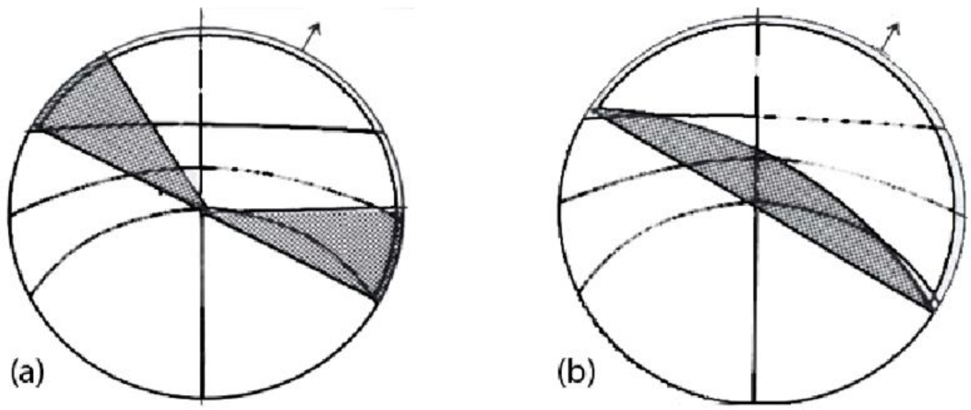


Fig. 3.20 : Superimposing shading mask on sun-path diagram
Source : (Szokolay, 2007)

5. The design process

Design of shading devices can be achieved using two methods which are traditional design method and the computer programs method. There are various traditional design methods based on solar path diagrams and shading masks. Both the Olgyays and Mazria's design methods are the most popular. As shown in fig. (3.21), the difference between the two methods is the type of solar projection used. The main advantage of traditional methods is that they easily show the relationship between the solar path, the overheating period and the required shade in one single picture. On the other hand, there are many computer design tools for design shading devices. The main advantage is that they can automatically give the optimum shading device geometry as a result of a set of input parameters (Dubois, 2000).

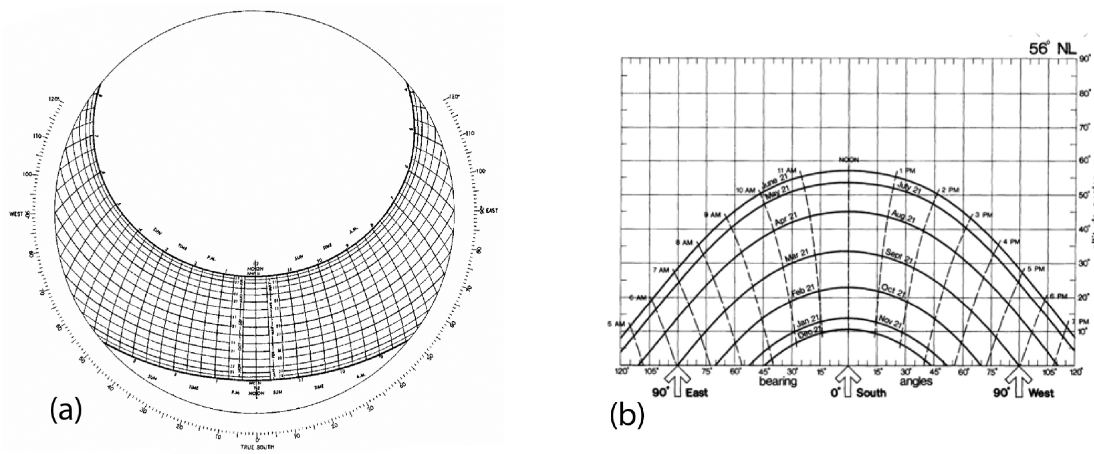


Fig. 3.21 : (a) Solar path diagram used by the Olgyays and (b) used by Mazria
Source : (Dubois, 2000)

according to Szokolay (2007) the process of shading design can be divided into three steps:

- Determine the overheated period which describes when shading is necessary, at what times of the year and between what hours of the day.
- Establish the necessary horizontal or vertical shadow angles (or a combination of the two) by using the appropriate sun-path diagram and the protractor, based on the required device to be designed
- Design the dimensions of device which satisfy required shade.

Conclusion

The previous chapter stated a general review about the definition and function of windows. In addition, the principles of energy efficient windows. It is clear that the window is an important element in the building envelope as it provides access to views, daylight and natural ventilation. Windows also can play essential function in the architectural appearance of the building. However, they are considered the weakest element for heat flow.

The total amount of this heat flow is specified by thermal transmittance (U-value), solar energy transmittance (g-value) and air leakage (L). Among these factors, the penetration of solar radiation through windows is considered the critical factor as it is the largest source of heat gain. For this purpose there are four factors, First, selecting the optimum window to wall area ratio (WWR) which allow less solar heat gain. Second, orientating windows to face prevailing wind and to exclude solar penetration. Third, using materials with low U-value. Fourth, using shading devices to block the solar radiation before it reach the indoor space.

Chapter

4

Impact of Windows Design on the Overall Energy Consumption

Introduction

It has been derived from the previous chapter that the affect of windows on the thermal performance of a building is specified by three factors which are: the thermal transmittance (U-value), total solar energy transmittance (g-value), and air leakage (L), which describe all amount of heat flow through a window. Thus, reducing heating and cooling loads requires controlling the penetration of heat flow caused by these factors. The thesis mainly focuses on solar and thermal transmittance through windows. This can be achieved by choosing the best orientation, size, glass material and shading devices. This chapter investigates the first three factors by simulating one storey building in the climatic condition of the Gaza strip, whereas factor of shading device will be discussed in the next chapter. The energy simulation software Ecotect and IES virtual environment are used to carry out the study and to calculate both heating and cooling energy demands of building in different cases. Then, comparison of the obtained results is performed to find which one reduces the energy consumption more.

4.1. Description of the climatic data

The Gaza Strip is considered a transition zone between the coastal area wetlands and the dry desert region (Negev desert in the south-east and Sinai desert in the south-west). It is located in hot humid region on longitude 34^0 26' east and latitude 31^0 10' north.

According to Palestinian Energy Authority (2011) winter in Gaza area is rainy and mild, while summer is hot and dry, and extends over longer period of the year. The following sections discuss in details the climatic elements of the Gaza strip.

4.1.1 Temperature

The average daily mean temperature ranges from 24°C in summer (May-August), to 15°C in winter (November-February). The average daily maximum temperature ranges from 27°C to 19°C, and minimum temperature from 21°C to 11°C, in the summer and winter respectively, (Palestinian Energy Authority, 2011). Fig. (4.1) shows the annual average temperatures (C) in the Gaza strip.

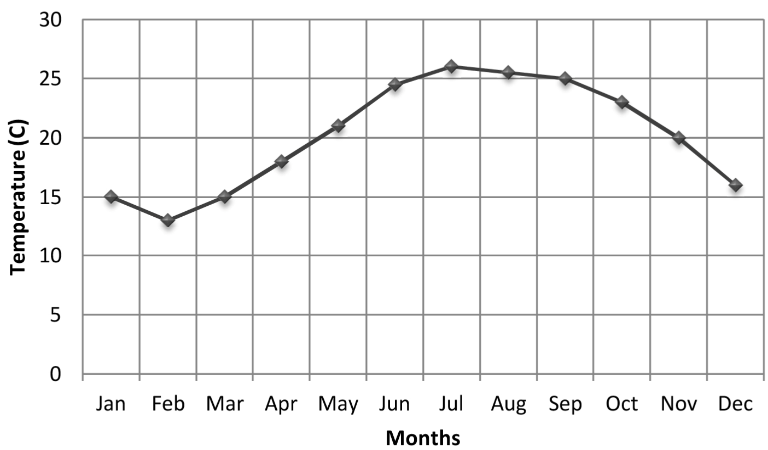


Fig. 4.1 : The annual average temperatures (C) in the Gaza Strip.
Source : (Ministry of Local Government, 2004)

4.1.2 Relative humidity

Relative humidity fluctuates between (65%) and (85%) in summer, and between (60%) and (80%) in winter. Fig. (4.2) shows the annual average Relative Humidity in the Gaza Strip (Ministry of Local Government, 2004). Rain is the main source of water in Palestine as it provides the underground water reservoir with water. Although rain fall in Gaza is unsteady, it is useful for irrigating farmlands. The amount of rain increases in the interior parts because these areas are higher than the sea surface. Annually, the amount of rain in the Gaza Strip is between 100-130 million m^3 (Kandeel, 2010).

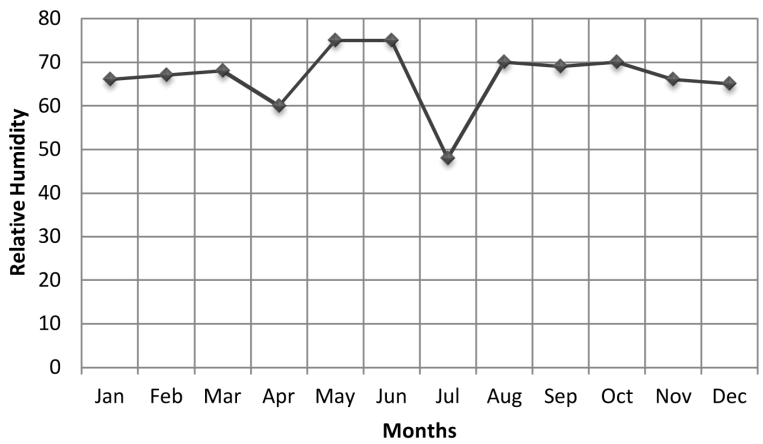


Fig. 4.2 : The annual average relative humidity (%) in the Gaza Strip
Source : (Ministry of Local Government, 2004)

4.1.3 Wind speed

The prevailing winds in the Gaza Strip is northwesterly in the summer. The speed of these wind is variable reaching the speed of (3.9) m/s during the afternoon. The prevailing wind direction and speed change during the winter, as it turns to the southwesterly wind and speed increase up to (4.2) m/s with non-volatile speed. Sometimes, it is noticed that there is blowing southwesterly winds increase up to (18) m/s (Ministry of Local Government, 2004). Fig. (4.3) shows the annual average wind speed (m/s) in the Gaza Strip.

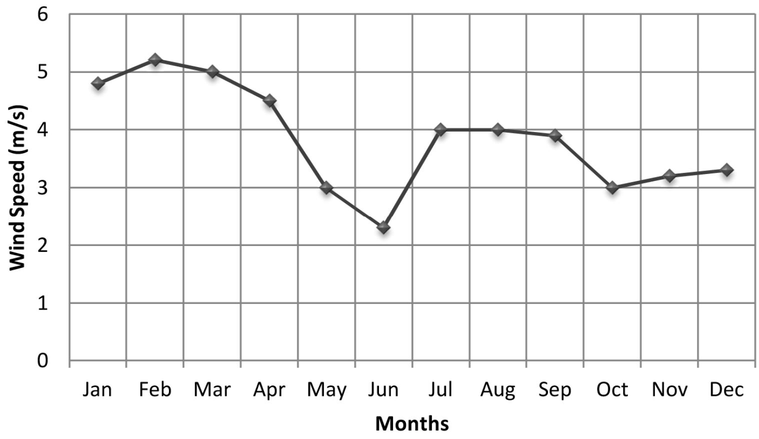


Fig. 4.3 : The annual average wind speed (m/s) in the Gaza Strip
Source : (Ministry of Local Government, 2004)

4.1.4 Solar radiation

According to Palestinian Energy Authority (2010) the Gaza Strip has a relatively high solar radiation. It has approximately 2861, annual sunshine -hour throughout the year. The daily average solar radiation on a horizontal surface is about 222 W/m^2 (7014 $MJ/m^2/yr$). This varies during the day and throughout the year. Fig. (4.4) illustrates the variation in the monthly daily average in total insolation on horizontal surface for each month.

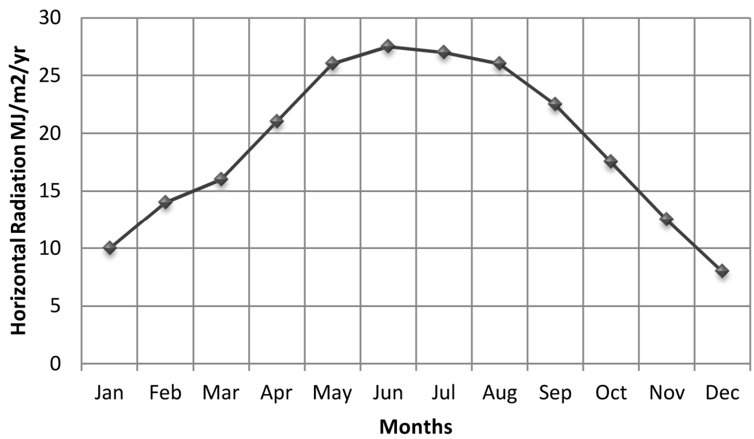


Fig. 4.4 : The annual variation in solar radiation ($MJ/m^2/day$) in the Gaza Strip
Source : (Palestinian Energy Authority, 2010)

4.2. Description of the model

The four factors investigated in the study can be divided into two groups. Fist group is the factors that are one of the window components. These factors should be considered in the early design stages including window orientation, size and thermal properties of glasses material. Second group is the factors that can added to existing window at any time as shading device. The first one is investigated in this chapter whereas the second is discussed in the next chapter.

This chapter aims to discuss the impact of the three factors including window orientation, size and glasses material on heating and cooling energy demand. The objective is achieved by study several alternatives in the climatic condition of the Gaza strip to select the lowest consumer of energy and to determine the rate of reduction. There are two models that will be simulated in the study using Ecotect and IES VE energy simulation software. The first model is a typical residential building located in the Gaza Strip region consisting of one storey with a single apartment, as shown in (4.5) and fig. (4.6).

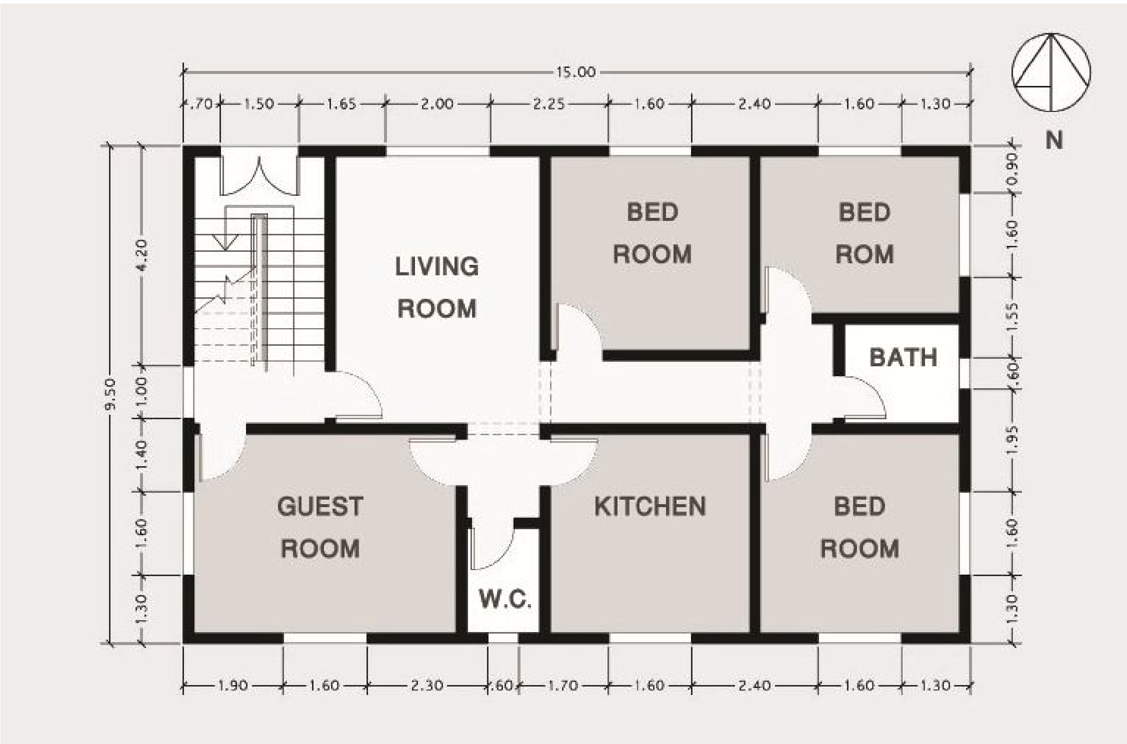
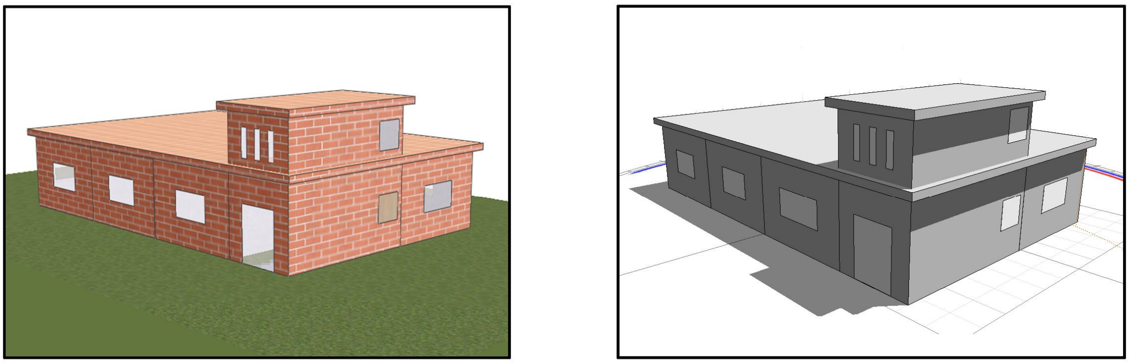


Fig. 4.5 : The ground floor of building model



Prospective - by IES VE　　　　Prospective - by ECOTECT

Fig. 4.6 : The perspective of building model

It is clear that the plan of the model takes rectangular form. Its longer axis is lied along east-west direction. It contains the stair which leads directly to the guest room and the living room, three bedrooms, kitchen, bath and guest toilet. The geometry of the model is taken as: (9.5m) width , (15m) length and (3m) height from floor to ceiling. The total floor area is (142.5 m^2) and the overall window area from this floor area is about (04%), (02%), (04%), and, (03%) for south, west, north, and east façade respectively. While the overall window area is about (11.6%), (09.1%), (11.6%), and , (12.7%) from south, west, north, and east façade area respectively. The considered windows sizes in the model is listed in table (4.1), as they are commonly used in the Gaza Strip.

Table 4.1 : The different sizes of windows in the model

	Width (m)	Height (m)	Sill Height (m)
Window size 1	2.0	1.0	1.0
Window size 2	1.6	1.0	1.0
Window size 3	1.0	1.0	1.0
Window size 4	0.6	0.7	1.3

Because there are a large number of residential buildings models in Gaza Strip, it is difficult to consider all of them in this study. The multi storey buildings is considered the common one in the Gaza Strip. However, the selected model is common in terms of the distribution of spaces in each apartment, and the dimensions of the windows.

The previous model is selected to study the effect of windows on overall energy consumption in realistic building as a case study, but the simulation results is predicted to match only the variables in this case. This depends mainly on the shape of plan and the size of windows in each façade. In order to study the direct effects of single window on the cooling and heating loads, an isolated room model is selected. As shown in fig. (4.7), the geometry of this room is chosen as: (4m) width , (4m) length and (3m) height. The room had one window in the south façade with (1.6) width, (1m) height.

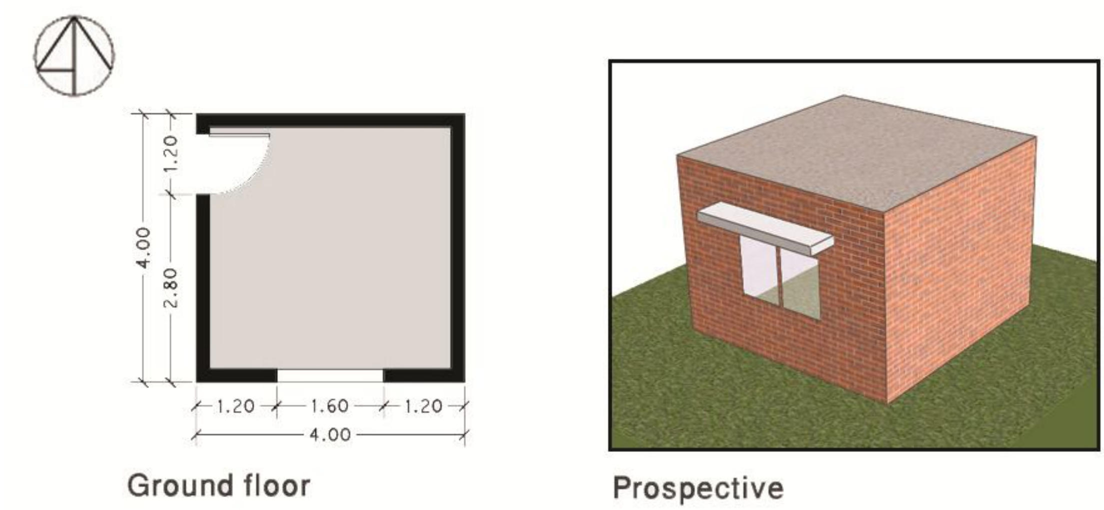


Fig. 4.7 : The geometry of single room model

4.3. Simulation tools

Integrated Environmental Solutions (IES) program is used in this study to simulate how the building will perform from an energy perspective over a whole year. In addition, Ecotect program is used to validate the results.

4.3.1 IES virtual environment

Integrated Environmental Solutions (IES) program performs thermal analysis for sustainable building design early in the design process. It includes several tools such as SunCast, Apache, FlucsDL, MacroFlo, ApacheHVAC. These tools performs several functions. Apache tool is used in this study which is the thermal simulation engine in IES Virtual Environment. It performs a dynamic thermal simulation using hourly weather data. It can Link data with the other ISE tools and it includes a wide range of applications which are:

- Thermal performance analysis
- Building fabric design
- Occupant comfort analysis
- Natural ventilation studies
- Façade analysis
- Energy consumption prediction
- Plant design and sizing
- Mixed-mode design
- Carbon emissions.

4.3.2 Ecotect

Ecotect Analysis offers several simulation applications during the earliest stages of design including:

- Calculate annual, monthly, daily, and hourly total energy use of the model.
- Calculate heating and cooling loads.
- Analyze effects of infiltration.
- Visualize incident solar radiation on windows and surfaces over any period.
- Display the sun's position and path relative to the model at any time.

4.4. Study parameters

There are mainly two factors determine the efficiency of energy consumption in buildings. First factor is the building design including location, layout, structure and building materials. Second factor is the patterns of building use. Thus, reducing the consumption of energy can be achieved through these two factors. This study considers the first factor, with a focus on the impact of windows design on the annual heating and cooling loads. The calculation of heating and cooling loads are influenced by four major components which are (Jaber, 2011):

- Solar heat gain.
- Heat conduction which depends on the thermal properties of the material
- Ventilation and infiltration.
- Internal loads.

In order to estimate the impact of windows design on the annual heating and cooling loads, the study will follow the following stages:

- Drawing the model with its specifications as described in (4.2) section.
- Selecting the climatic data including solar radiation, temperature and relative humidity as mentioned in (4.1) section.
- Determining thermal comfort temperature range. In this study it is assumed to be from (18°C to 26°C).
- Then, the study will investigate four parameters including:
  - Window size in each facade which will be ranged between (10% to 90%).
  - Orientation.
  - Window glass U value.
  - Shading device for south, east and west facades by changing its depth from (0.1 m to 2.0 m).
- The output data of simulation will be discussed in more details in the following sections.

4.5. Results and discussion

The three major factors are studied separately to examine the actual impact of each factor on cooling and heating loads. The following sections discuss the results of simulation programs in order to select the optimum design.

4.5.1 Orientation

The aim of this investigation is to examine the influence of rotating the building on heating and cooling energy demand to find out optimum orientation angle. The optimum orientation angle which is defined here as that at which the building has a minimum energy requirement. The south facade is set as a reference to rotate the building and the orientation angle is changed from (90^0 to -90^0) in (10^0) as shown in fig. (4.8). The heating and cooling energy demand of the building is determined at each orientation.

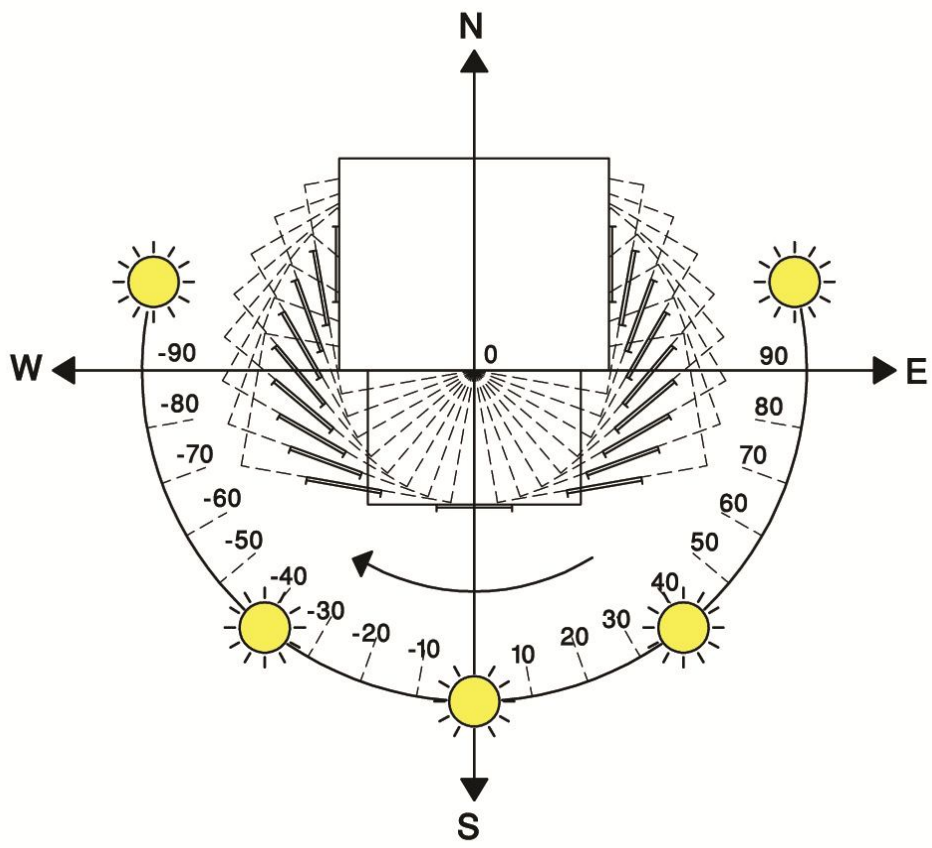


Fig. 4.8 : Changing the orientation of south facade from 90^0 to -90^0 in 10^0

The orientation factor will be examined in the following sections for both building and room models which are described in section (4.2).

1. Building model

Fig. (4.9) shows the total annual heating and cooling energy at different orientation angles. It is clear that the total heating energy needed to provide comfort throughout the year is greatly less than the total cooling energy. For example, at angle of 90^0 (east orientation), the annual heating energy is (0.55 MWh) while the annual cooling energy is (6.26 MWh).

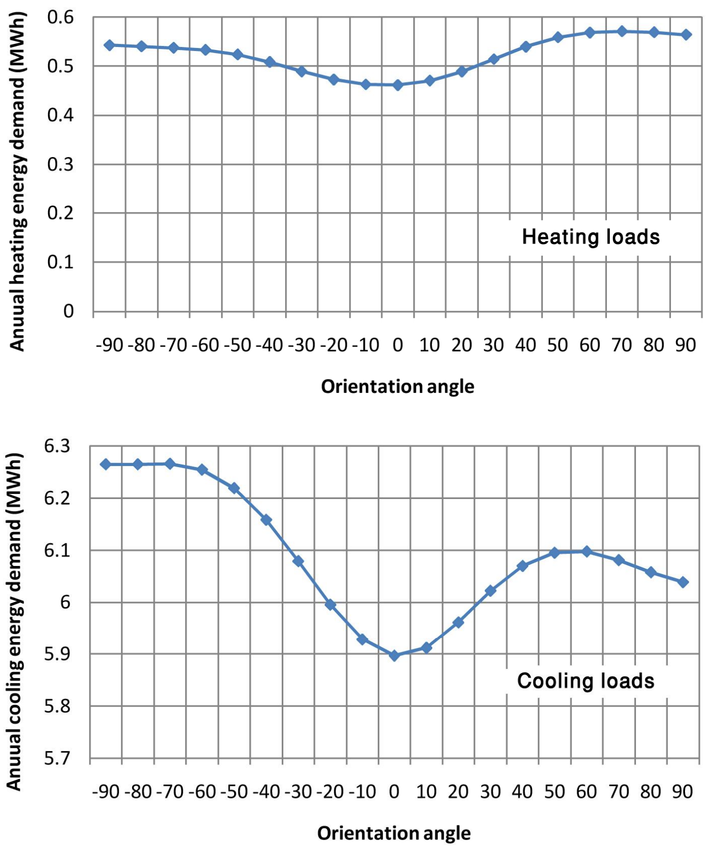


Fig. 4.9 : The total annual heating and cooling energy at different orientation angles Building model - BY IES VE

This difference between heating and cooling energy is referred to the climatic conditions of the Gaza Strip which is located in hot humid region. The temperature of this climate in most of the year is high which means that it requires more cooling loads to reach thermal comfort level.

To determine the optimum orientation, the annual energy demands including heating and cooling in total value will be considered. From fig. (4.10) and according to IES VE results, it is clear that the energy needed in both heating and cooling is the lowest when the orientation angle is zero, which means that orienting the long axis of the building along the east–west axis is the best orientation for energy saving. It is also seen that between (0^0 to -90^0) orientation, the maximum energy is occurred at angle of (-70^0) (which is 30 degrees from west to south). While from (0^0 to 90^0) orientation, the maximum energy is achieved at angle of (60^0) (which is 40 degrees from east to south). This means that the worst orientation is occurred at these two angles.

To validate the previous results which are obtained by IES VE software, another thermal simulation is carried out using ECOTECT. Fig. (4.10) shows good agreement between the results of the two simulation programs. Both confirm that the lowest cooling and heating load is obtained at zero orientation angle, whereas the highest cooling and heating load is obtained at (-70^0) and (60^0) angles. This means that the results are reliable. It is also observed that there is different in energy needed values between two simulations. This is returned to the different of thermal properties of the building materials installed in each model, which are not considered in this simulation.

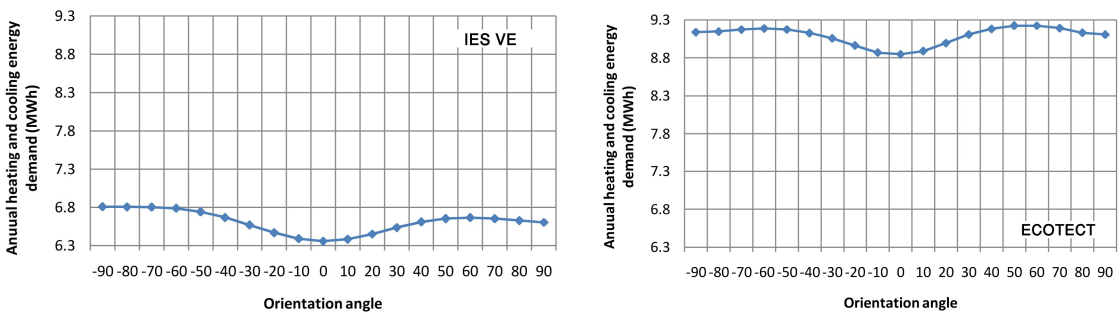


Fig. 4.10 : The overall annual heating and cooling energy at different orientation angles - Building model

Based on previous results, orienting the long south façade, which contains the large number of windows directly to south causes less energy consumption than deviating it to west or east. This is referred to the changing windows position in relation to solar radiation according to the orientation angle. The intensity of this solar radiation which is received by these windows is differed according to sun azimuth and altitude angles. In addition, when sun facing south window, the altitude angle of sun is high. In this case, solar radiation enters through window to short distance in the space. While east and west windows receives solar radiation at low angle. Therefore, radiation enters for long depth.

2. Room model

In the previous building model, there are several variables beside windows orientation affecting the energy loads. One of these is that the existing of windows on all facades, therefore solar radiation received by them is not equal. This causes uncertainty in determining the net impact of specific window in each façade. For this reason, a separate room shown in fig (4.6) is investigated also from ($+90^0$ to -90^0) in 10^0, see fig. (4.8). The simulation results of this room model are presented in fig (4.11). It is seen that orienting the window 10 degrees from south to west is the best direction. The large energy loads is obtained at east direction with angle of (90^0). The energy load of west direction at (-90^0) angle is also high, but its value is less than east window.

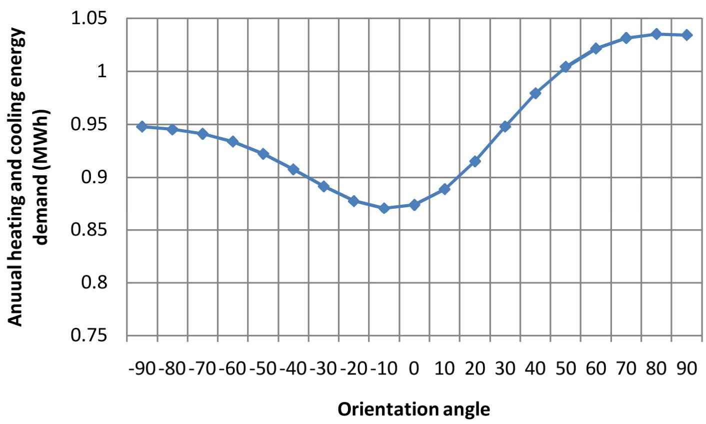


Fig. 4.11 : The total annual heating and cooling energy at different orientation angle Room model - BY IES VE

From south to east, it is seen that increasing the orientation angle by (10^0) increases energy demand approximately at a steady rate with (3%). While this rate from south to west is (2%).

It is obvious that both building and room simulations confirm that the large dimensions of a building should preferably face north and south, because these elevations receive the lowest heat loads from solar radiation. This indicates that elongating the long axis of the building along east-west direction can be used as appropriate orientation, see fig. (4.12). The results also indicate that the windows of east and west facades cause the large energy consumption. Therefore, using windows in these elevations should be minimized as possible or installed with shading devices. For example, placing unnecessary spaces which don't need high level of daylight such as stairs and stores can effectively help in achieving less window percentage in these elevations.

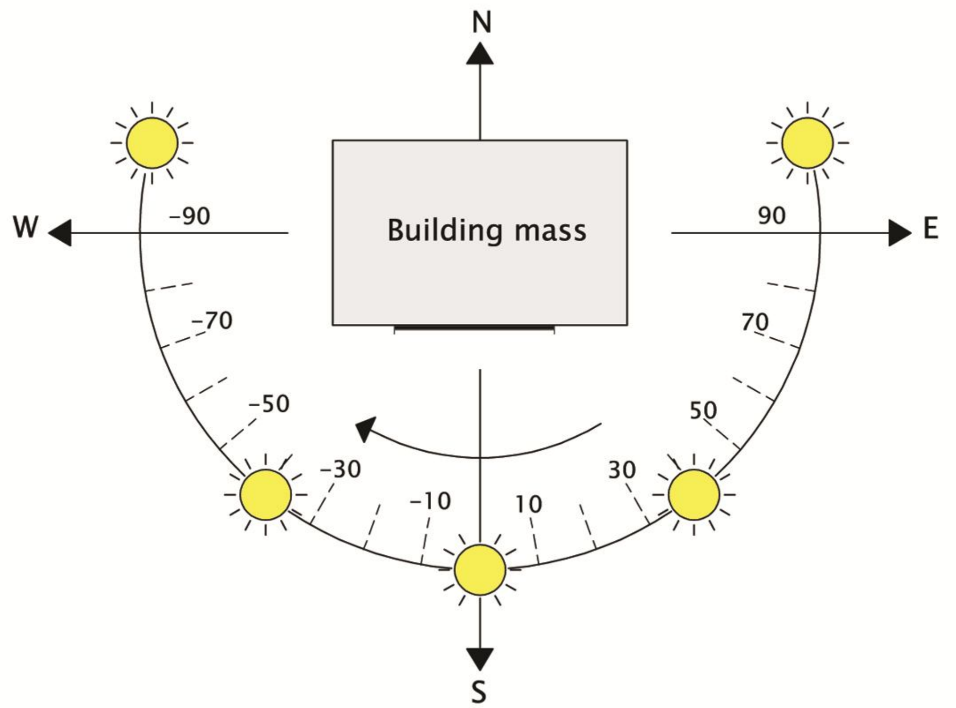


Fig. 4.12 : The optimum orientation

4.5.2 Windows size

This investigation is carried out to examine the impact of window size on heating and cooling energy demand and to find out the optimum size. By using IES VE and ECOTECT software, the simulations are run for both building and room models. Different window sizes from the total façade area are selected between 10% to 90%, see fig. (4.13). The heating and cooling energy demand is estimated at every size and in each facade. Both horizontal and vertical shapes of windows are investigated to see the thermal performance of each shape.

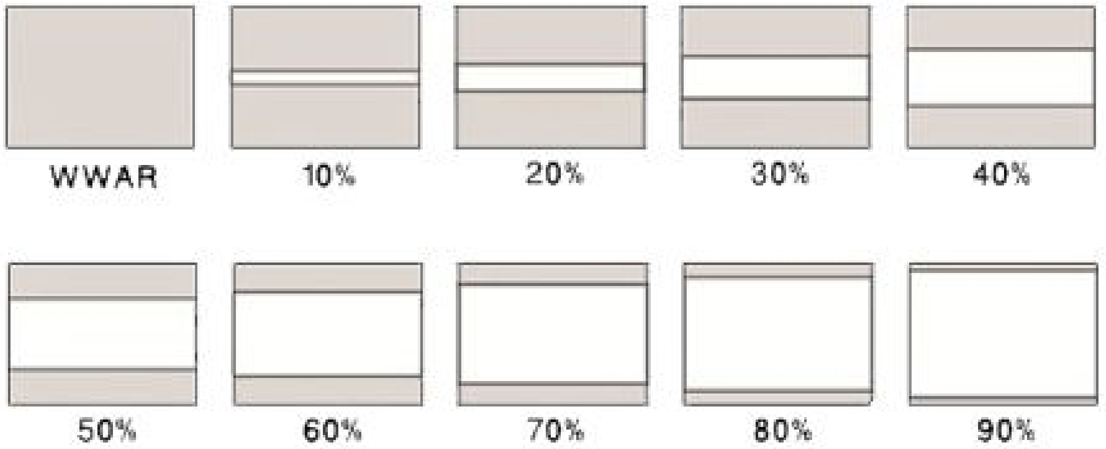


Fig. 4.13 : Window to wall area ratio used in building and room simulations

Both building and room models which are described in section (4.2) of this chapter also will be simulated in the following sections to determine the effect of changing window size on energy consumption:

1. Building model

Fig. (4.14) presents the heating and cooling demand of building model for all elevations at each ratio. It is obvious that increasing the size of windows decreases heating loads and increases cooling loads. For example, using the window to wall area ratio (WWAR) of 40% instead of 30% for south facade decreases the annual heating demand by 12.5% with an average energy (0.0317 MWh), whereas it increases by 24% with an average load (0.0602 MWh) for WWAR of 20%.

On the other hand, increasing windows size in each façade increases the cooling load linearly and rapidly. For example, using WWAR of 40% instead of 30% for south facade increases the annual cooling demand by 20.6% with an average energy (1.8781 MWh), whereas it decreases by 20.3% with an average load (1.8508 MWh) for WWAR of 20%.

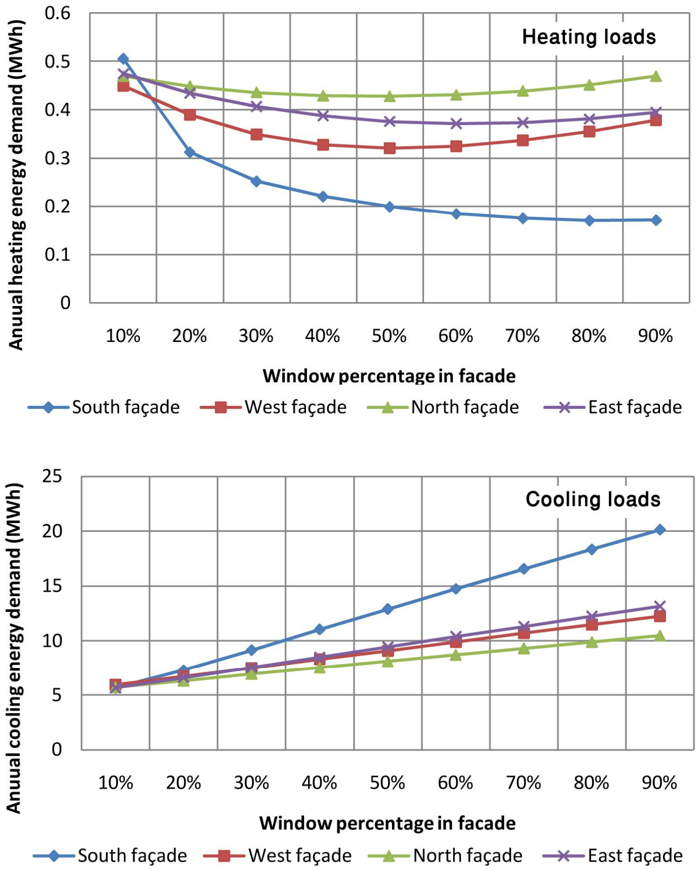


Fig. 4.14 : The total annual heating and cooling energy at different windows size Building model – BY IES VE

Based on previous results increasing the window percentage is desirable for heating purpose in the winter, but it is not preferred for cooling purpose in the summer. However, it does not have a major influence on heating demand and its saving rate can be ignored. The reason for this is the hot temperature of the Gaza Strip climate. This justifies giving the priority to reduce cooling demand by decreasing size of windows to lowest percentage as much as possible rather than to reduce heating demand.

The summation of annual primary energy demand of a building model is presented in fig. (4.15). According to IES VE results in left of the figure, it is seen that for all facades increasing the window size by 10% increases the energy load approximately at a steady rate, but the value of this rate differs from façade to another, see table (4.2) which shows this difference in increasing rate.

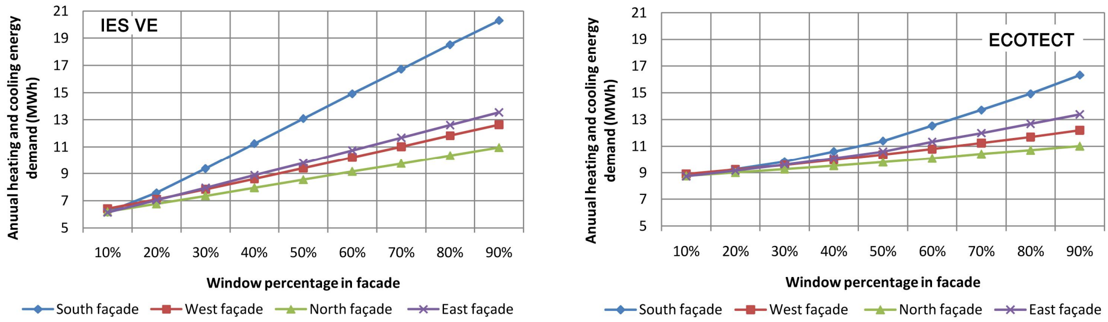


Fig. 4.15 : The overall annual heating and cooling energy at different windows size for - Building model

ECOTECT results in right of fig. (4.15) shows largely considerable agreement with IES VE output. It is seen that both simulation confirm that increasing the window percentage leads to increase energy loads steadily. Thus, the output of simulation can be relied on.

Table 4.2 : The increasing rate of annual energy consumption due to the increase of the windows size by 10%

	Increase rate (%)	Average load (MWh)
South facade	30	1.8
West facade	12	0.8
North facade	10	0.6
East facade	15	0.9

It can be concluded from previous results that the optimal percentage of windows for all facades at which the building has a minimum energy load is the less size. In addition, the impact of each facade on energy consumption can be ordered as south, east, west and north facade respectively from the high to the low. For example at 90% size, the total annual heating and cooling energy is (20.3 MWh) for south façade, (12.6 MWh) for west façade, (10.9 MWh) for north façade and (13.5 MWh) for east façade. The south façade is considered the most facade affecting on energy consumption, so determining its windows size must be done carefully.

Beside factor of solar radiation amount received by each elevation, this variation between the four facades is influenced also by the difference of overall window area factor in each facade. Previous simulation is carried out for windows with horizontal shape as shown in fig. (4.13). Another simulation is carried out for windows with vertical shape to examine the impact of changing shape beside size on thermal performance of windows as shown in fig. (4.16). Fig. (4.17) shows the result of this investigation.

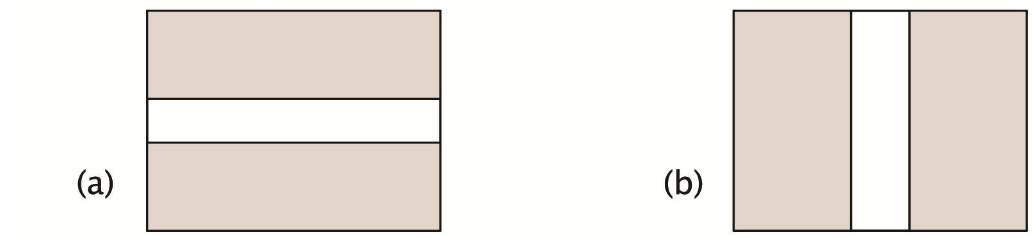


Fig. 4.16 : (a) horizintial shape and (b) vertical shap of (20%) window size

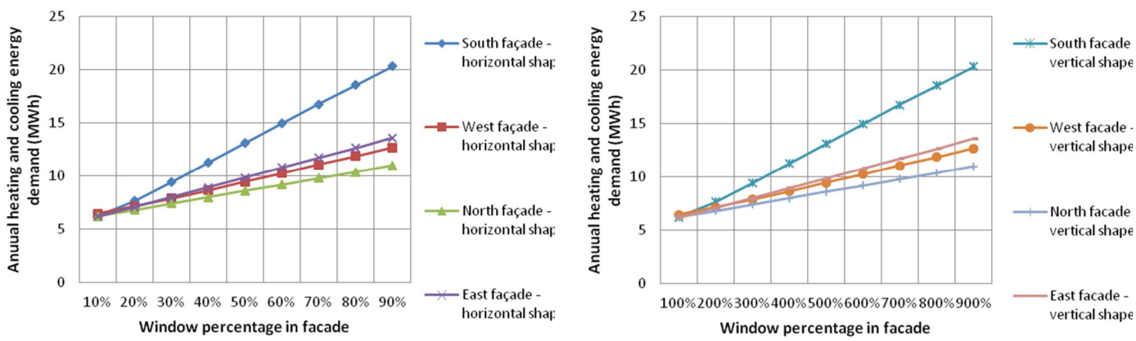


Fig. 4.17 : Comparison between the horizontal and vertical shape at different windows size Building model – BY IES VE

It is clears that both shapes causes the same energy loads. Thus, it can be confirmed that the thermal performance of building isn't influenced by using vertical shape instead of horizontal shape. While the thermal component of windows is affected by the local climatic conditions, especially solar radiation.

2. Room model

The window size factor is also studied using IESVE software in the room model to see the direct impact of each elevation on required energy loads. Different windows size between 10% to 90% from the total façade area as shown in previous fig. (4.13) is also investigated. The equivalent of these from the floor area is presented in table (4.3).

Table 4.3 : The window size percentage of total façade area and its equivalent of floor area

From the total façade area	10%	20%	30%	40%	50%	60%	70%	80%	90%
From the total floor area	7.5%	15%	22.5%	30%	37.5%	45%	52.5%	60%	67.5%

The results of simulation is shown in fig. (4.18), as in building model, it shows that increasing the window size for all facades by 10% increases the energy load approximately at a steady rate with linear trend. This rate is 44% in south façade, 16% in west façade, 12% in north façade, 14% in east façade. It is clear that the large consumption is caused by south façade whereas the lowest is caused by north façade. This refers to the variable amount and intensity of solar radiation passing through each façade.

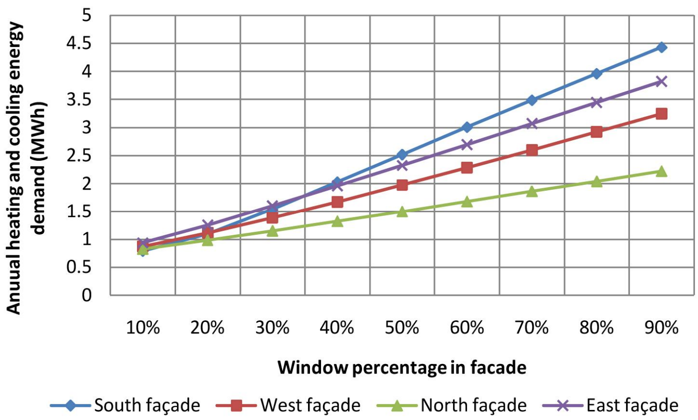


Fig. 4.18 : The annual heating and cooling energy at different windows size Room model - BY IES VE

Both building and room simulation emphases two main points. First point, the optimum window size for all facades is the minimum percentage of size. Second point, Elevations can be arranged in terms of their impact on energy consumption as south, east, west and north facade respectively from high to low. Therefore, these two considerations must be taken into account in early design process of any building. Minimizing size of windows to low percentage may be unacceptable in terms of providing the required natural light. The following section examines the effect of changing size on this factor.

3. Daylight factor

As mentioned in literature review of the study, besides thermal performance factor, daylight provision also should be taken into account when selecting the optimum window size. For this purpose, eight scenarios summarizing all possible alternatives of window positions are selected as shown in fig. (4.19). Both horizontal and vertical shapes of these are studied using IES VE software to investigate the impact of window size on the average of natural daylight level. The appropriate illuminance level is not absolute value, but it is differed depending on the type of activity. In this study, the acceptable level is chosen as a range of (100 to 300 lux) to match the residential buildings activities.

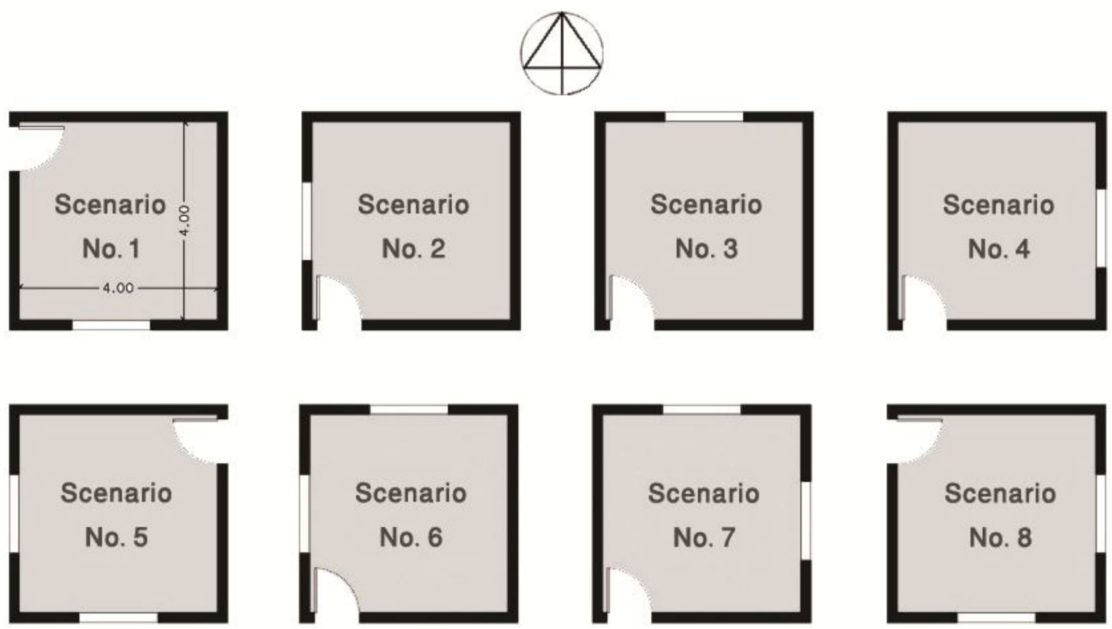
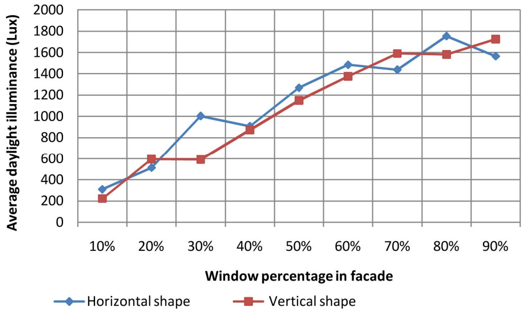
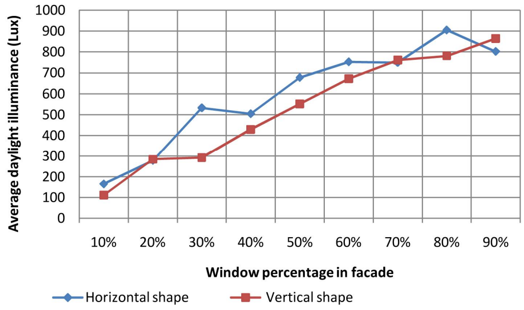


Fig. 4.19 : Eight possible alternatives of window position

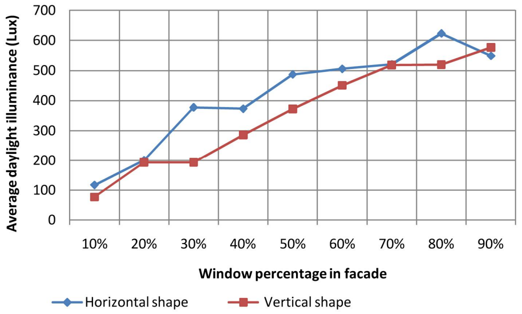
Fig. (4.20) shows the simulating results for the eights scenarios. For scenario (no.1), for example, the best size range for both horizontal and vertical shapes is the same and it is (10%). Table (4.5) gives a summary of the optimum size for the eight scenarios. It is seen that the minimum size at 10% provides sufficient daylight in scenario No. 1,2,3,4,6,7. While scenario No. 5 (south and west window) and scenario No. 8 (south and east window) give over acceptable light at all sizes including 10% (the less size), see fig. (4.20) and table (4.4).



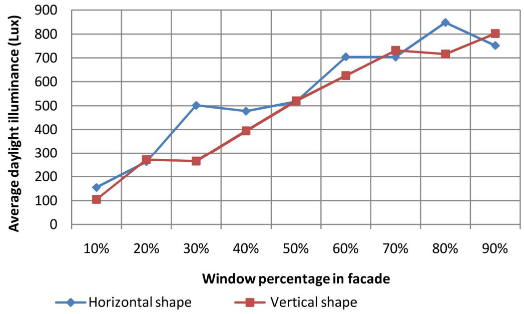
Scenario No. 1



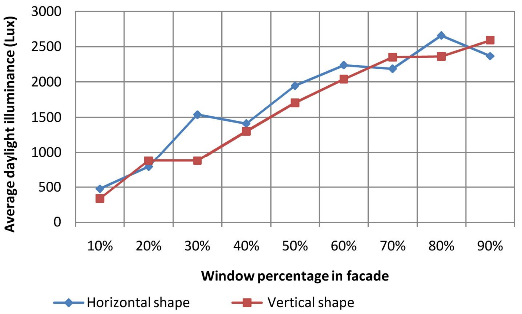
Scenario No. 2



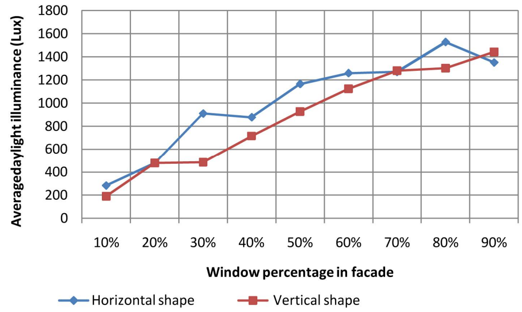
Scenario No. 3



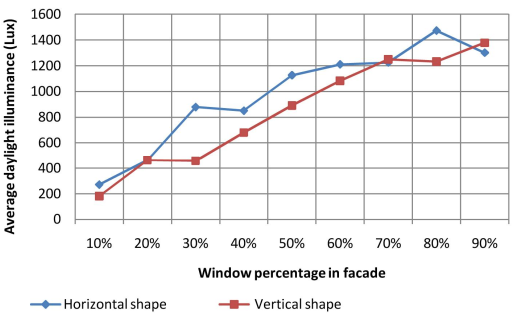
Scenario No. 4



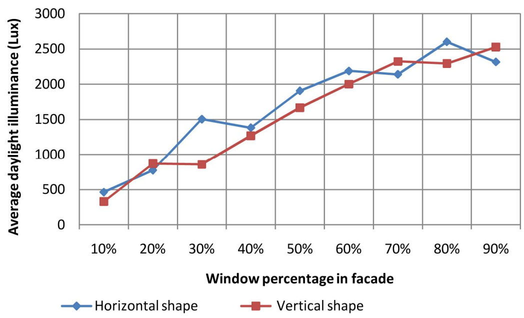
Scenario No. 5



Scenario No. 6



Scenario No. 7



Scenario No. 8

Fig. 4.20 : The average of daylight illuminance (Lux) for the eight scenarios at horizontal and vertical shapes Room model - BY IES VE

Table 4.4 : The optimum size range for all scenarios that give the acceptable level of light

	Description	Optimum size range for horizontal shape	Optimum size range for vertical shape
Scenario No. 1	South window	10%	10%
Scenario No. 2	West window	From 10 to 20%	From 10 to 20%
Scenario No. 3	North window	From 10 to 20%	From 20 to 40%
Scenario No. 4	East window	From 10 to 20%	From 10 to 30%
Scenario No. 5	South and west window	Over acceptable	Over acceptable
Scenario No. 6	West and north window	10%	10%
Scenario No. 7	North and east window	10%	10%
Scenario No. 8	East and south window	Over acceptable	Over acceptable

It can be concluded that less size of 10% offers the best alternatives in terms of thermal comfort and visual comfort for all scenarios excepting (No. 5) and (No. 8). While, using large percentage in all options, such as 20% in scenario (no.1), should be avoided because it causes glare that affects visual comfort.

4.5.3 Thermal properties of glass material

Heat gain and loss through window also depends on the thermal properties of the material and on its effective heat capacity. This part of the study is going to identify the relation between the energy consumption and the thermal properties of the window glass. Seven types of glass materials are used in this simulation. The thermal properties of these materials which includes U values, transparency and solar Heat Gain Coeff. are listed in table (4.5)

Table 4.5 : U values, Transparency and solar heat gain coeff. of glass materials used in simulation

	U Values ($W/m^2.k$)	Transparency (0-1)	Solar Heat Gain Coeff. (0-1)
U1 : Double glazed with timber frame, emissivity of 0.10.	2.26	0.92	0.75
U2 : Double glazed with aluminium frame (no thermal break), emissivity of 0.10.	2.41	0.92	0.75
U4 : Double glazed with timber frame.	2.90	0.92	0.75
U5 : Translucent skylight.	5.00	0.81	0.78
U6 : Single pane of glass with timber frame.	5.10	0.92	0.94
U7 : Single pane of glass with aluminium frame (no thermal break).	6.00	0.92	0.94

In this simulation, the selected materials can be divided into two types which are double and single glass. Table (4.6) and table (4.7). illustrates thermal conductivity, density, specific heat and thickness of these types.

Table 4.6 : Thermal conductivity and thickness of double glass material

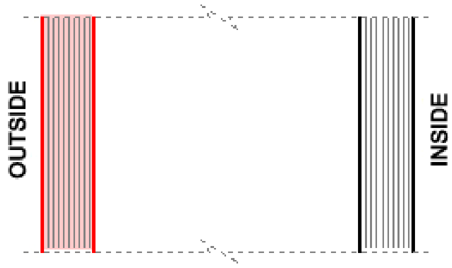
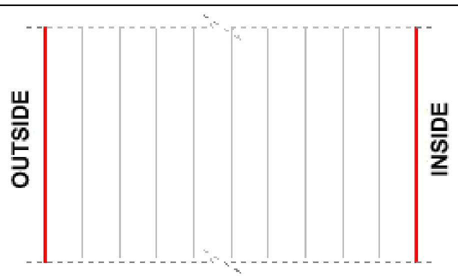
	Thickness (m)	Density (kg/m^3)	Specific heat (Wh/kg °C)	Thermal conductivity (W/m^2 °C)
Glass Standard	6.0	2300.0	836.800	1.046
Air Gap	30.0	1.3	1004.000	5.560
Glass Standard	6.0	2300.0	836.800	1.046
Section				

Table 4.7 : Thermal conductivity and thickness of materials used for single glass

	Thickness (m)	Density (kg/m^3)	Specific heat (Wh/kg °C)	Thermal conductivity (W/m^2 °C)
Glass Standard	6.0	2300.0	836.800	1.046
Section				

Using ECOTECT and IES VE software, the annual heating and cooling loads of the building model is estimated for the previous different U values of glass materials. The results of both simulation are presented in fig. (4.21) and

(4.22). The figures show that the cooling and heating energy loads decrease as the U value of glazing material is decreased. According to IES VE, this saving reaches to 19% by using glasses with U value (2.26) instead of (0.6).

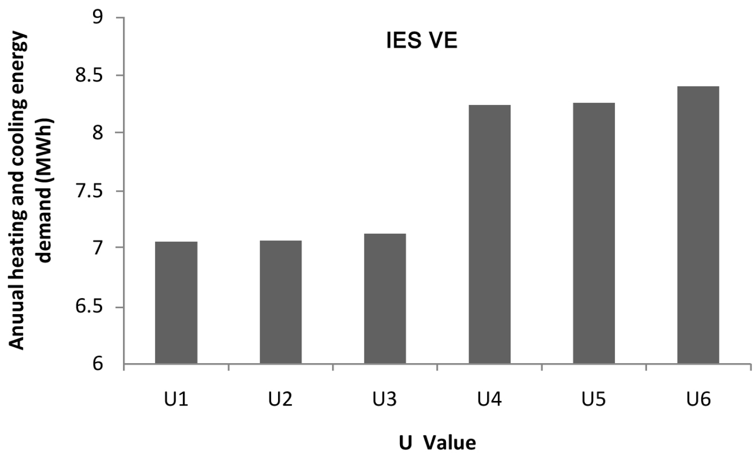


Fig. 4.21 : The total annual heating and cooling energy at different U values Building model - BY IES VE

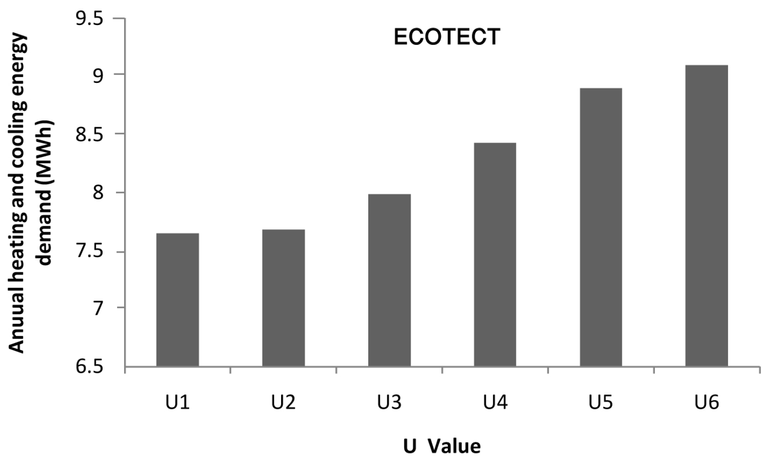


Fig. 4.22 : The total annual heating and cooling energy at different U values Building model - BY ECOTECT

In the light of above findings, it can be concluded that using advanced glazing materials with low U-factor (thermal transmittance) can play important role in reducing the energy consumption of building.

Conclusion

This chapter discussed the impact of windows on heating and cooling energy demand. In particular, it studied three factors which are window orientation, window size and thermal properties of glasses material. One storey building and isolated room are simulated in the climatic conditions of the Gaza strip using Ecotect and IES virtual environment software.

It has been concluded that the long axis of the building should be elongated along the east-west direction. In addition, the impact of window direction on energy consumption can be ordered as south, east, west and north window respectively from the high to the low.

The study also emphasized that the minimum percentage of windows with (10%) is the best size as it causes the less consumption of energy. Besides thermal factor, this less percentage can also offer the optimum option in terms of visual comfort. By changing the shape of window besides the size, it has been found that the thermal performance of building isn't influenced by using vertical shape instead of horizontal shape.

The chapter also presented the impact of thermal properties for glasses material on energy consumption. It has been concluded that a advanced glazing materials with low U-value can play important role in reducing the energy requirement of building.

Chapter

5

Impact of Shading Devices Design on the Overall Energy Consumption

Introduction

As mentioned in literature review of the study, shading devices can play an important role in controlling the solar radiation that enters into the room especially during summer months. This chapter is carried out to study the impact of shading devices on energy demand and to find out the optimum shading device depth. It mainly focuses on the facades that are exposed to direct solar radiation, which includes south, west and east façade, while north facade has not been studied because it does not receive direct solar radiation and shading is not necessary on it. The window size with (1.6) width and (1m) height is the only size investigated, because it is commonly used in the Gaza Strip buildings. Among the different types of shading devices, the study mainly deals with the external devices that includes vertical, horizontal and combined devices. The simulation is also carried out, as in previous chapter, using Ecotect and IES virtual environment software to calculate both heating and cooling energy demands of the building and room models at different assumed depths.

5.1. Shading devices of south facade

Because the angle of the sun is high when it faces south façade, the most appropriate and effective devices for this façade is the horizontal shading devices. ECOTECT software can automatically give the optimum horizontal device geometry by selecting the window object and the overheated period which identifies the times of the year and between what hours of the day shading device is the most desirable.

In order to determine the overheated period, cooling loads and direct solar gains of building through the year are taken as an indicator. The high monthly cooling loads is considered to present the overheated months, while the high daily direct solar gains is considered to present the overheated hours.

The following fig. (5.1) shows the monthly heating and cooling energy of the building without shading devices.

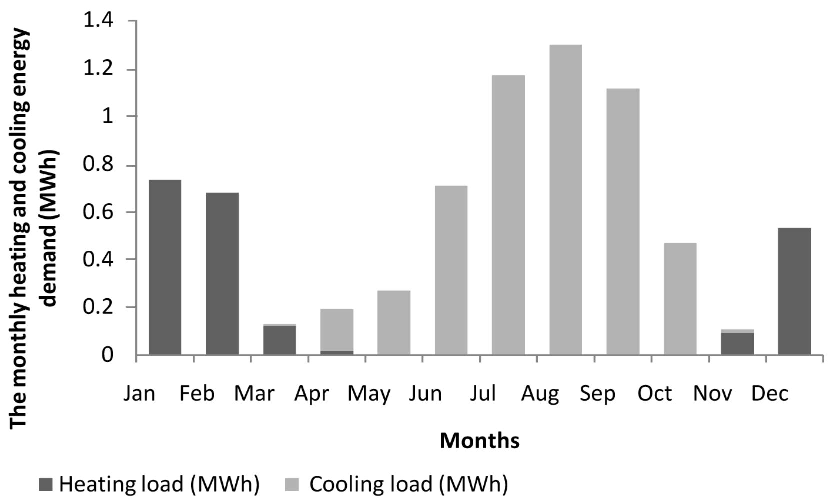


Fig. 5.1 : The monthly heating and cooling energy demands without shading devices Building model - BY ECOTECT

From the figure, it is clear that the cooling loads occurs on April, May, June, July, August, September and October months. Next table (5.1) also shows the daily direct solar gain of the building without shading device. It is seen that, during April to October months, the high level of direct solar gain occurs from morning (07:00 AM) to evening (15:00 PM).

Table 5.1 : The daily direct solar gain of the building without shading device

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	4	5	3	0	0	0	0	0
6	0	0	5	20	31	30	29	23	13	11	2	0
7	56	77	83	37	47	53	51	44	71	165	233	70
8	175	284	246	134	57	50	66	89	275	420	442	290
9	562	604	593	302	117	56	81	218	518	685	776	758
10	870	946	844	423	230	85	142	320	721	953	1061	1183
11	1129	1142	853	520	307	186	222	369	670	1031	1311	1469
12	1103	1124	655	487	292	183	215	307	539	941	1149	1238
13	951	926	505	400	224	150	174	240	385	671	912	989
14	683	648	423	262	121	99	113	170	290	417	547	682
15	388	404	301	136	60	73	69	101	186	232	283	322
16	31	123	123	42	37	46	43	34	65	26	2	0
17	0	0	1	5	15	21	21	12	1	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0

It can be concluded that the overheated period is the seven months from April to October and between (07:00 AM to 15:00 PM). Therefore, full shading should be provided during this period. Both building and room models which are described in the section (4.2) in previous chapter also will be simulated in the following sections to determine the effect of changing shading devices depth on heating and cooling demand and to find the optimum depth.

5.1.1 Building model

The investigation is carried out via computer programs ECOTECT and IES VE, but there is a difference in the way of two simulation tools in determining the optimal shading device depth:

Using ECOTECT software, the optimum depth of horizontal shading device can be selected automatically by inserting the overheated period which is (from April to October and between 07:00 AM to 15:00 PM) and by selecting the window object which its size is (1.6m width and 1.0m height). It has been found that the optimum horizontal shading device depth for this window size is (0.9m). It is relatively large depth for window with (1.0m) height.

On the other hand, IES VE software doesn't give the optimum depth automatically, but there is a need to check the heating and cooling requirement at several assumed depths to see at which depth the building has a minimum energy requirement. Here, the values are chosen from (0.0m) to (1.8m) to be around the optimum value (0.9m) that is obtained by ECOTECT software. Fig. (5.2) shows the total annual heating energy in above and cooling energy in below for Building model by IES VE simulation.

It should be mentioned that the simulated building is exposed from all sides. The figure gives a comparison between heating and cooling loads at different depths of horizontal device. It is clear that increasing the depth of horizontal shading device from (0.0m) to (1.8m) leads to rapid increase in the total annual heating energy. In contrast, the total annual cooling energy is decreased. However, the amount of increasing in heating load is largely less than the amount of saving in cooling load. For example, when the depth is increased from (0.8m) to (0.9m), the heating load is increased with an average load (0.0019 MWh), while the cooling load is decreased with an average load (0.0112 MWh). This means that the using the appropriate depth of horizontal shading device can effectively help in protecting the window from solar radiation during the summer months, hence reducing required cooling loads. Besides this positive point, it obvious that installing shading devices for south façade increases heating loads. This indicates that it also prevents some of the desirable solar radiation in winter. But this negative impact can be ignored because the total heating load in general is largely less when it is compared with saving in cooling load.

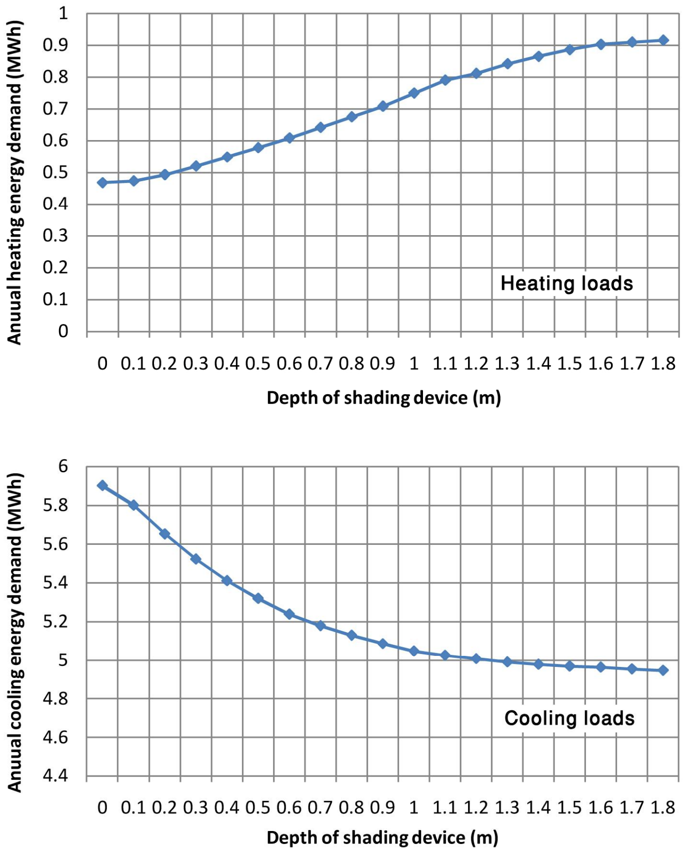


Fig. 5.2 : The total annual heating and cooling energy *<u>for south façade</u>* at different horizontal device depth Building model - BY IES VE

Fig. (5.3) shows the total annual heating and cooling energy for south façade at different horizontal devices depth for Building model. According to IES VE results in left of the figure, it is seen that the loads reaches the highest value at zero depth which represents the window without shading device. While it drops below to the lowest value at depth of (0.9m). It is also clear that increasing the depth from (0.0m) to (.9m) have a major influence on saving the heating and cooling requirement. Whereas any increasing of the depth from (1.0m) to (1.8m) relatively isn't effective, and it may increase the cost of device construction without any considered saving in energy. Therefore, for the building model, the optimal depth of horizontal shading device for south window with (1.0m) height is the depth of (0.9m), see fig. (5.4). This means that the depth of (0.9m), can provide fully protect for the window from solar radiation during summer months, and can admit as much as possible of direct sun in winter.

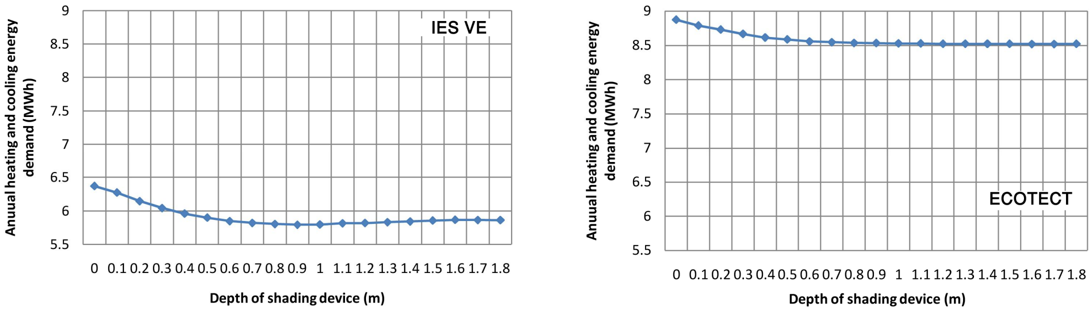


Fig. 5.3 : The overall annual heating and cooling energy *<u>for south façade</u>* at different horizontal device depth for Building model

It is obvious from the fig. (5.3) that the annual energy load is (6.37 MWh) at depth of (0.0m), whereas it is (5.79 MWh) at the optimum depth of (0.9m). Thus, it can be concluded that installing horizontal shading device with the optimum depth on south windows can reduce the energy consumption by (09%) comparing to that case of no shading device. To validate these results, the output of ECOTECT simulation in right of fig. (5.3) shows generally good agreement with that of IES VE, as the relation between energy loads and shading depth widely take the same curve in both simulation.

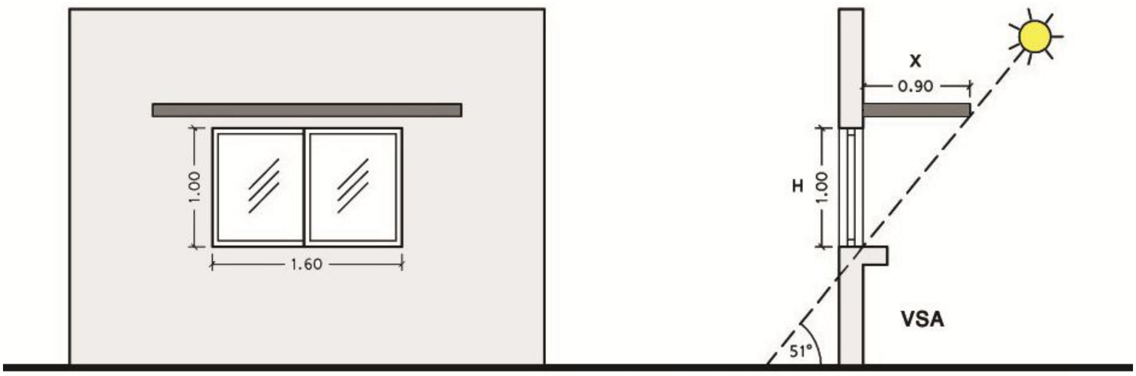


Fig. 5.4 : The elevation and section of the optimal horizontal device

From the architecture point of view, the use of long shading device depth such as (0.9 m) for window with (1.0m) height is possible to be unacceptable appearance. Using many combinations of horizontal elements with the same vertical shadow angle (VSA) that can give the same shading performance, as shown in fig. (5.5), can offer potential solution for this problem.

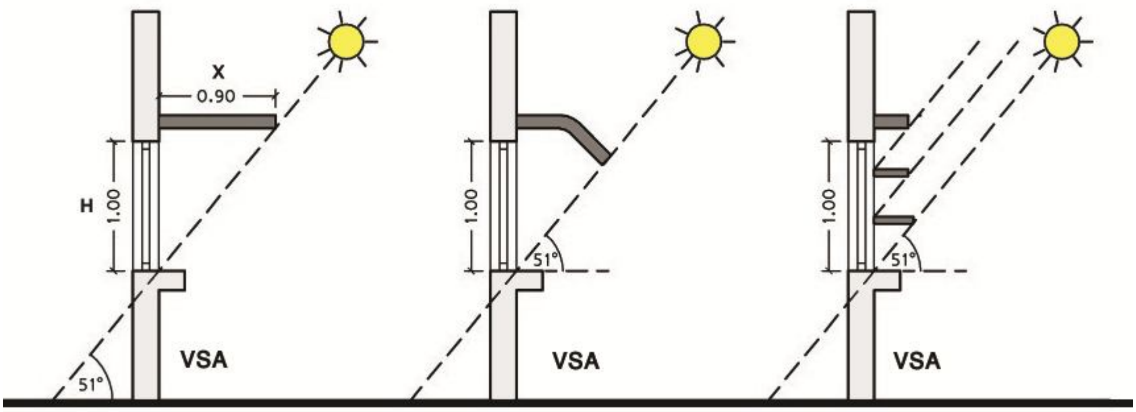


Fig. 5.5 : Different shapes for the optimum horizontal device giving similar shading performance

5.1.2 Room model

The previous section studied the horizontal devices at the south facade for the suggested building model. It has been found that using the best depth of (0.9m) can reduce the energy consumption by (0.9%). This section investigate the optimal depth of horizontal devices for the single south window (with 0.1m height and 1.6m width) in single room model to determine the direct impact of shading devices, using EOTET software,

Fig. (5.6) shows the results of this simulation. It is seen that the less value of total annual heating and cooling energy is obtained when the depth is set as (0.4m). Thus, the optimum depth is the (0.4m) depth, see fig. (5.7). It is clear that there is difference in the optimal depth between building and room model. This confirms that the depth of shading device isn't only depended on size of window and incidence angles of solar radiation, but it is also influenced by the design and the form of building. Therefore, the previous optimum value can not be considered as a standard to all cases, but each case must be simulated separately to determine the appropriate depth of shading device for its design.

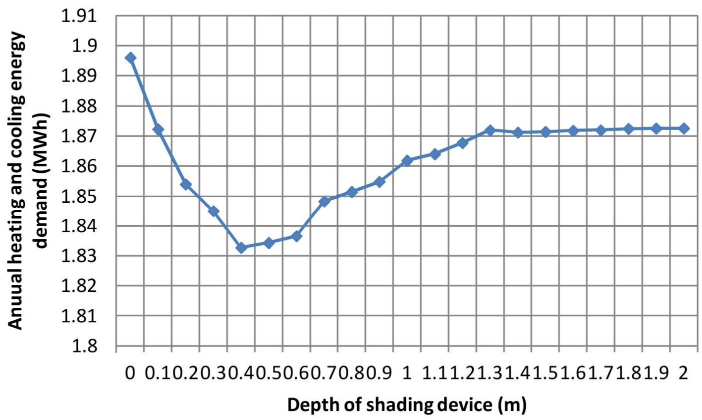


Fig. 5.6 : The total annual heating and cooling energy *<u>for south façade</u>* at different horizontal device depth Room model - ECOTECT

The annual energy load is (1.9 MWh) at zero depth which is the case of window with no shading. Whereas the loads is (1.8 MWh) at the optimum depth of (0.4m). This means that the direct impact of using the optimum horizontal shading device on south window is that it can reduce the consumption by (5.5%).

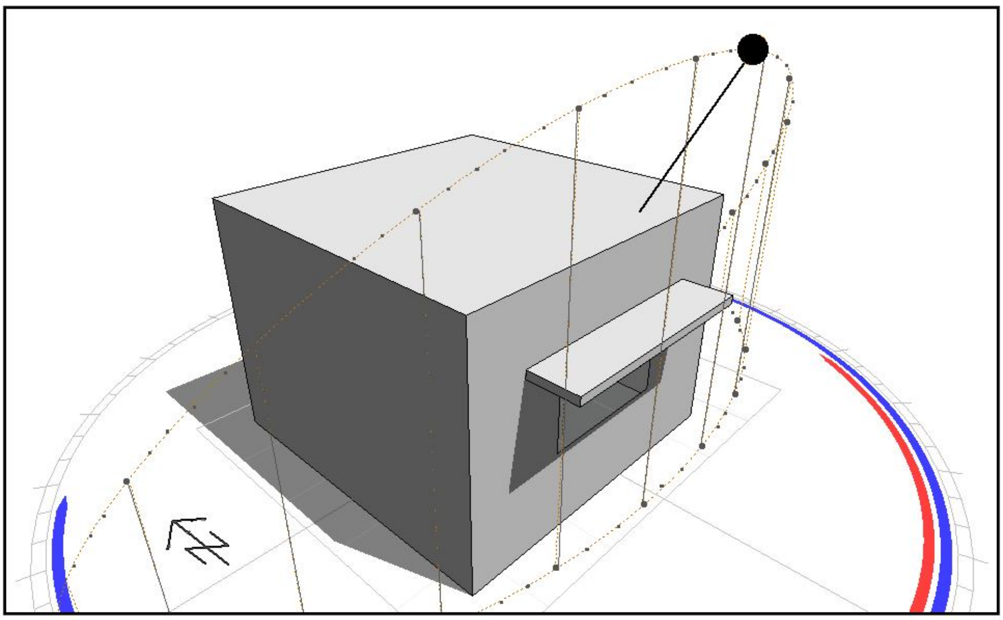


Fig. 5.7 : The shading performance of the optimal device depth for south window

The previous room with the optimum depth of (0.4m) for south window is oriented as shown in fig. (5.8) to examine the influence of deviation room on the effectiveness of optimum depth. The heating and cooling energy demand of the room is determined at each orientation, see fig. (5.9).

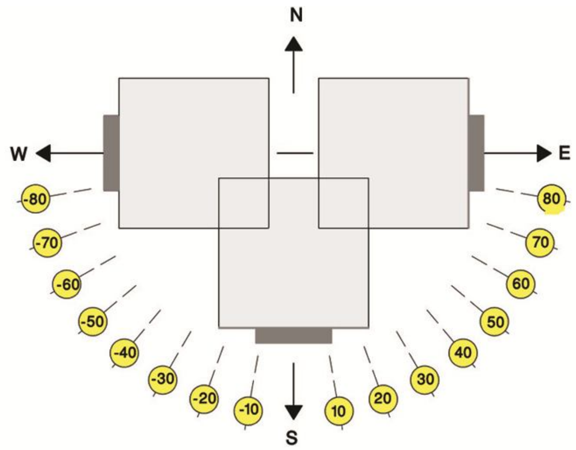


Fig. 5.8 : Changing the orientation of south window with optimum shading devices from 90^0 to -90^0 in 19 steps

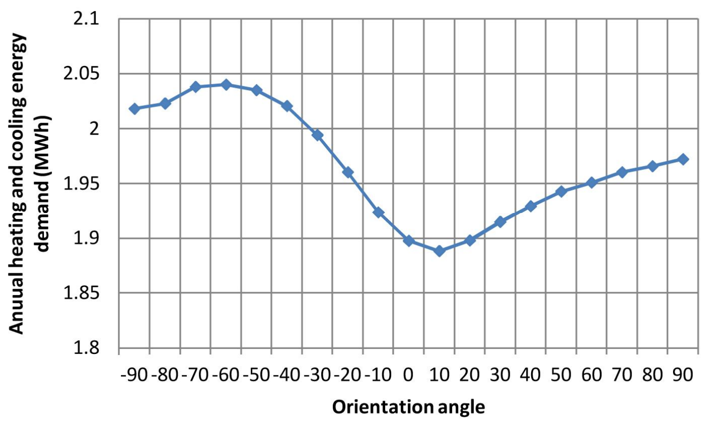


Fig. 5.9 : The total annual heating and cooling energy *for south façade* with optimum device at different orientation angles - Room model

Fig. (5.9) shows that the heating and cooling demand increases by changing the orientation angle. This means that the optimum depth of (0.4m) is suitable only for the south direction without any deviation. In general, the required heating and cooling loads are influenced by many factors. One of these factors is the direct solar gain. Fig. (5.10) presents the monthly direct solar gain that causes by the south window. It shows a comparison between the two cases of shading and non shading device.

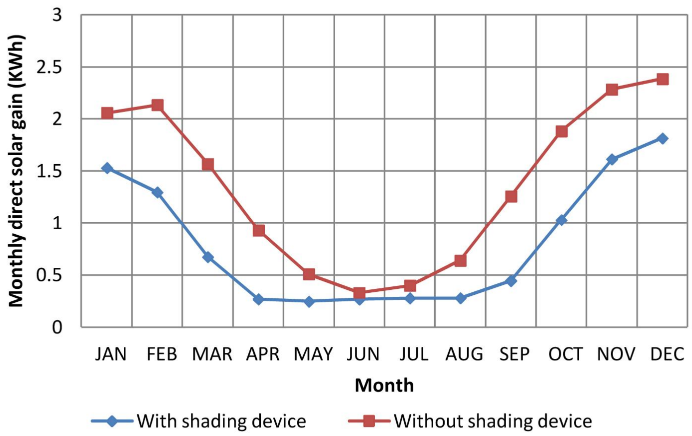


Fig. 5.10 : The monthly direct solar gain of room model with and without shading

It is clear that shading devices can play important role in reducing the amount of solar gain, and hence reduce the cooling demand. On the other hand, the effect of using optimum depth (0.4m) on inside temperature is also investigated. Temperature values are obtained for the average hottest day (30th April) to represent summer conditions, and for the average coldest day (12th January) to represent winter conditions. The results is illustrated in table. (5.2).

Table 5.2 : Hourly temperature values in the average hottest and clodest days

Average hottest day (30th April)					Average coldest day (12th January)				
Hr.	Outside Temp. (^{0}c)	Inside Temp. (^{0}c) without shading	Inside Temp. (^{0}c) with shading	Temp. different	Hr.	Outside Temp. (^{0}c)	Inside Temp. (^{0}c) without shading	Inside Temp. (^{0}c) with shading	Temp. different
6	23.2	26.2	26.4	- 0.2	**6**	5.9	11.1	11.1	0
7	24.2	26.1	26.2	- 0.1	**7**	7.5	10.9	10.9	0
8	24.6	25.9	26.1	- 0.2	**8**	9.4	11	11	0
9	27.3	26.1	26	0.1	**9**	11.2	11.5	11.4	- 0.1
10	30.8	27.4	26.7	0.7	**10**	11.2	11.7	11.5	- 0.2
11	35.5	28.7	27.7	**1**	**11**	9.6	11.5	11.5	0
12	36.8	28.9	27.9	**1**	**12**	9.5	12.3	12.3	0
13	38.3	30.9	30.1	0.8	**13**	10.5	13.9	13.9	0
14	39	31.9	31.5	0.4	**14**	13.2	14.3	14.1	- 0.2
15	39.8	32.3	32.1	0.2	**15**	13.6	13	14.8	- 0.2
16	39.2	31.9	31.8	0.1	**16**	13.5	12.1	12.1	0
17	38	33	33.1	- 0.1	**17**	12.4	12.3	12.4	0.1
18	35.3	33.2	33.2	0	**18**	10.3	13.8	13.9	0.1

The values clearly describe the change in temperature. For example, it is seen that the temperature reducing reaches the maximum value in hottest day at (11:00 am) and (12:00) am with (1) temperature degree.

5.2. Shading devices of west facade

This section investigates the optimal shading devices for the west orientation in both building and room models. In addition, it investigate the reduction ratio on energy consumption as a result of using shading devices:

5.2.1 Building model

When the sun opposites west façade, its angle is high in midday time. While it turns into low position at end of the day. As a result, the most effective device is the compound type which is a combination of horizontal and vertical elements. In order to find the optimum depth for the west windows (that is with 1.6m width and 1.0m height), both devices including horizontal and vertical are increased by the same value, see fig. (5.11). Then, the energy load is calculated at several depths which is chosen from (0.0m) to (2.0m), see the results in fig. (5.12).

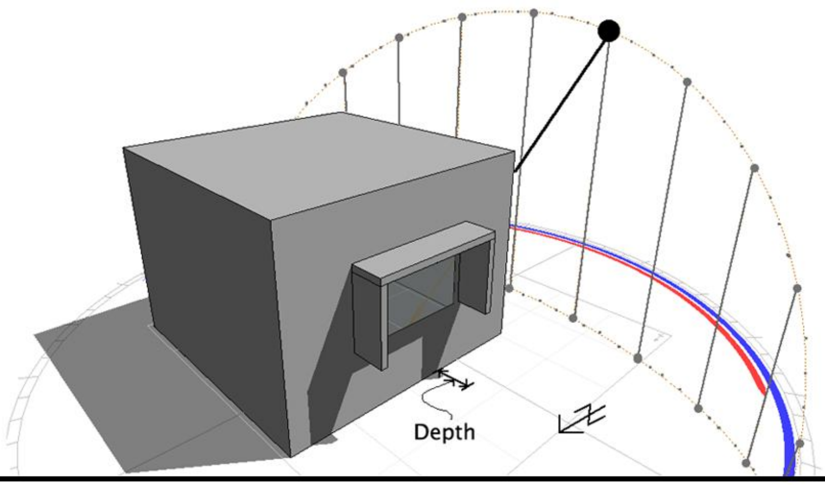


Fig. 5.11 : Increasing horizontal and vertical devices (compound) by the same value

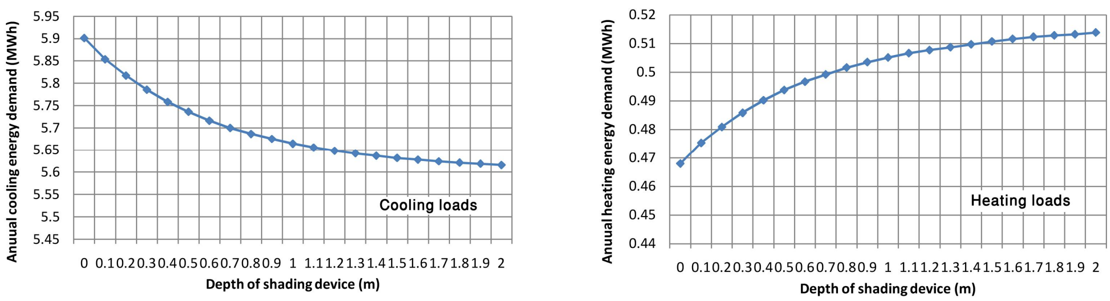


Fig. 5.12 : The total annual heating and cooling energy *for west façade* at different horizontal device depth Building model - BY IES VE

The results in the figure shows that there is a difference between the curve of heating and cooling energy load. It is clear that the heating increases, while the cooling decreases. However, the increasing rate of heating load is largely less than the saving rate of cooling load. Thus, this undesirable increasing in heating loads can not be taken into account. To select the best depth, the energy loads is considered as a total including heating and cooling, as shown in fig. (5.13).

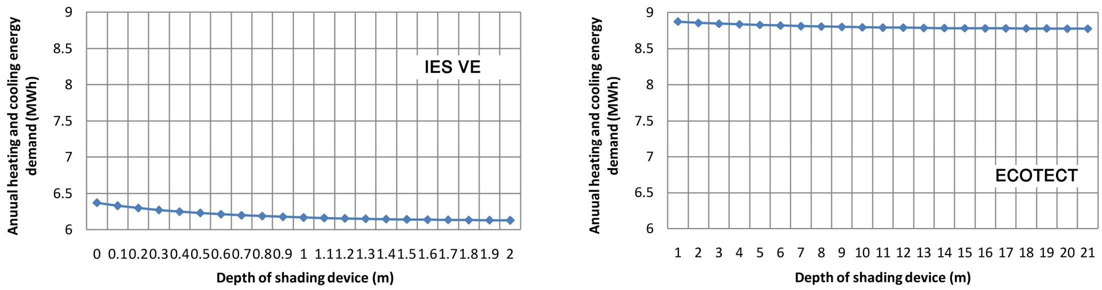


Fig. 5.13 : The overall annual heating and cooling energy *<u>for west façade</u>* at different horizontal device depth for Building model

According to IES VE results in left of the figure, the decreasing rate of total annual heating and cooling energy from (0.0m) to (2.0m) reaches the maximum at the small depths, whereas it decreases as the depth increases to reach the minimum at the 2.0m depth. For example, the decreasing rate is (0.04 MWh) between (0.0 m) depth and (0.1m) whereas it is drops below to (0.002 MWh) between depths of (1.9m) and (2.0m).

In can be concluded that using compound shading device with (0.2m) depth instead of (0.0m) can reduce energy consumption by (3.8%). The results of ECOTECT in the figure largely validates the previous results of IES VE. Both simulations confirm that the (2.0m) is the best depth which causes the low loads.

5.2.2 Room model

Fig. (5.14) shows the results of simulating the direct effect of compound shading device for single west window (that is with 0.1m height and 1.6m) in the separate room. It shows that the annual energy load is (0.95 MWh) at zero depth which is the case of no shading, whereas the loads is (0.80 MWh) at depth of

(0.2m). The curve shows that the optimum is the depth of (1.9m), because any increasing in depth doesn't make considerable reduction in energy consumption.

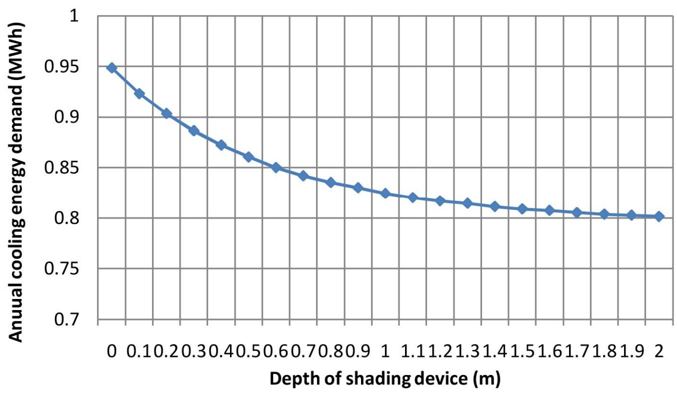


Fig. 5.14: The total annual heating and cooling energy for west façade at different horizontal device depth Room model - BY IES VE

It is clear that using (1.9m) depth instead of (0.0m) depth leads to saving in heating and cooling load by 16%. However, the depth of (1.9m) is relatively large and unacceptable for the architecture appearance. Thus, there is a need to use many combinations elements, as shown in fig. (5.15).

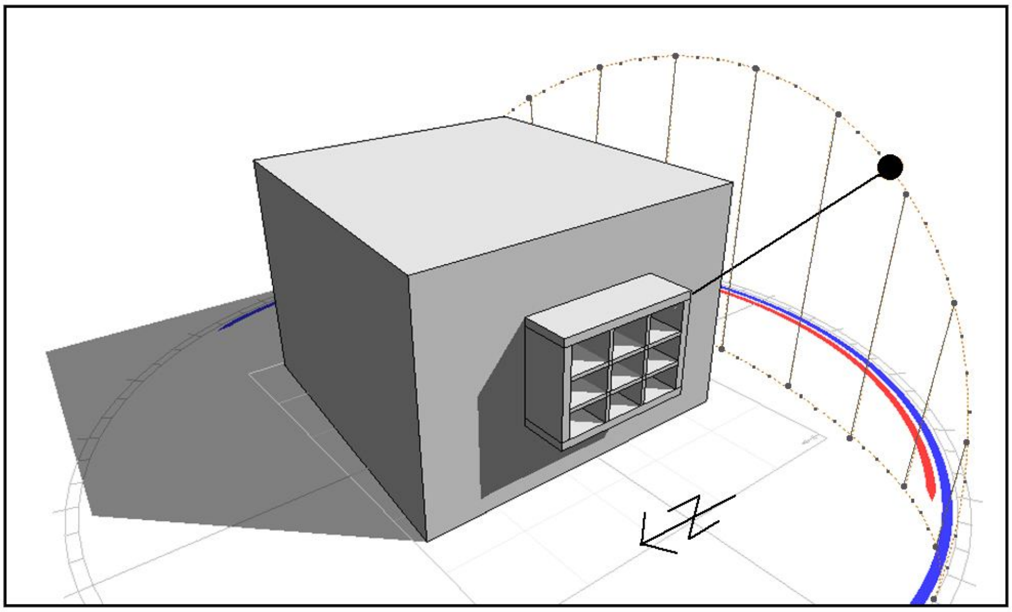


Fig. 5.15 : The shading performance of the optimal device depth for west window

5.3. Shading devices of east facade

Both horizontal and vertical devices is also investigated in east façade by increasing them with the same value. The energy load is calculated at several depths from (0.0m) to (2.0m) to find the optimal depth for the window (that is with 1.6m width and 1m height) in building and room models.

5.3.1 Building model

As in west and south facades, the next fig. (5.16) shows that using shading devices for east façade increases heating loads and decreases cooling loads. However, the increasing in heating is largely less than saving in cooling energy.

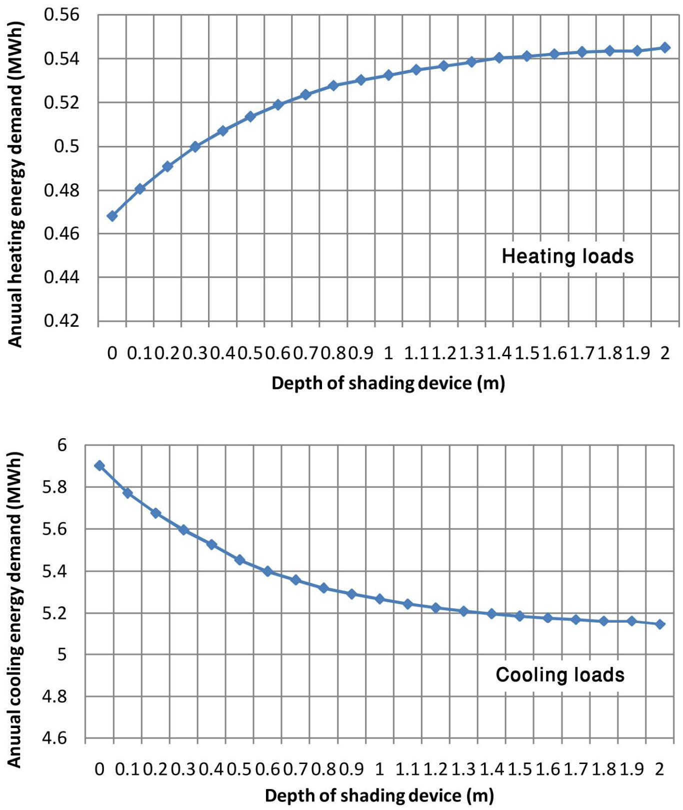


Fig. 5.16 : The total annual heating energy in above and cooling energy in below for west façade at different horizontal device depth Building model - BY IES VE

Fig. (5.17) generally shows that there is good agreement between the simulation which is carried out by ECOTECT and IES VE programs. Both simulations emphasize that the decreasing rate on energy loads from (0.0m) to

(2.0m) goes down, as the depth increases. According to IES VE results, the energy demand can be reduced by 11% when the depth is set as (2.0m) instead of (0.0m) which represents the window without shading.

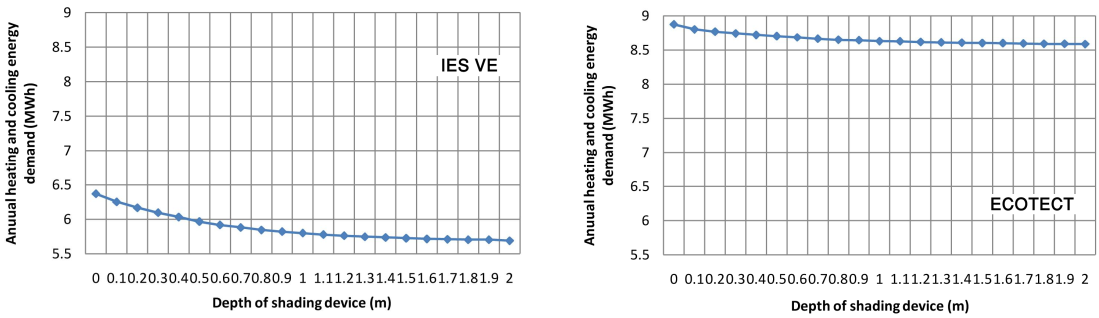


Fig. 5.17 : The total annual heating and cooling energy *for east façade* at different horizontal device depth Building model - BY IES VE

5.3.2 Room model

Fig. (5.18) shows the results of simulating the net impact of horizontal and vertical shading device for single east window in the separate room. The simulation is carried out by IESVE program for window size with (0.1m) height and (1.6m) width. As shown in the fig, increasing the depth from (0.0m) to (1.5m) leads to drop the heating and cooling energy demand with non equal rate, while changing the depths from (1.5m) to (2.0m) gives the same shading performance without any affect on saving energy.

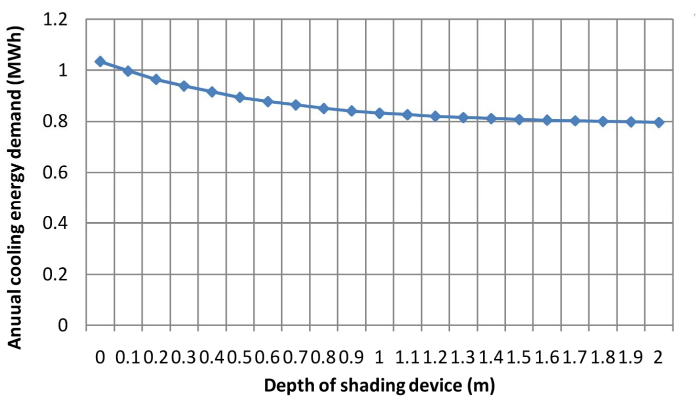


Fig. 5.18: The total annual heating and cooling energy *for east façade* at different horizontal device depth Room model - BY IES VE

It is seen that the maximum energy demand is (1.03 MWh) at zero depth (no shading), whereas the minimum is (0.80 MWh) at the optimum depth of (1.5m). This means that the heating and cooling loads can be reduced (23%) by using the optimum compound shading device depth with (1.5m) on east window, instead of leaving it without shading. Figures (5.19) and (5.20) show the potential of using many combinations of vertical elements with the same vertical shadow angle (HSA) that can give the same performance of (1.5m) depth.

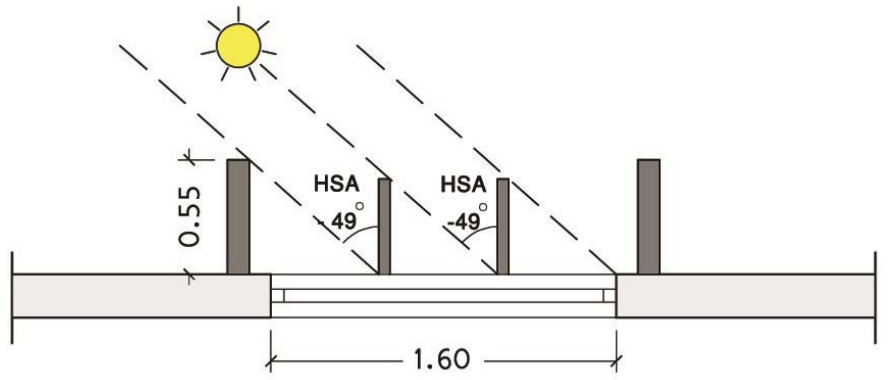


Fig. 5.19 : Using many combinations of vertical elements instead of 1.5 m depth for east window

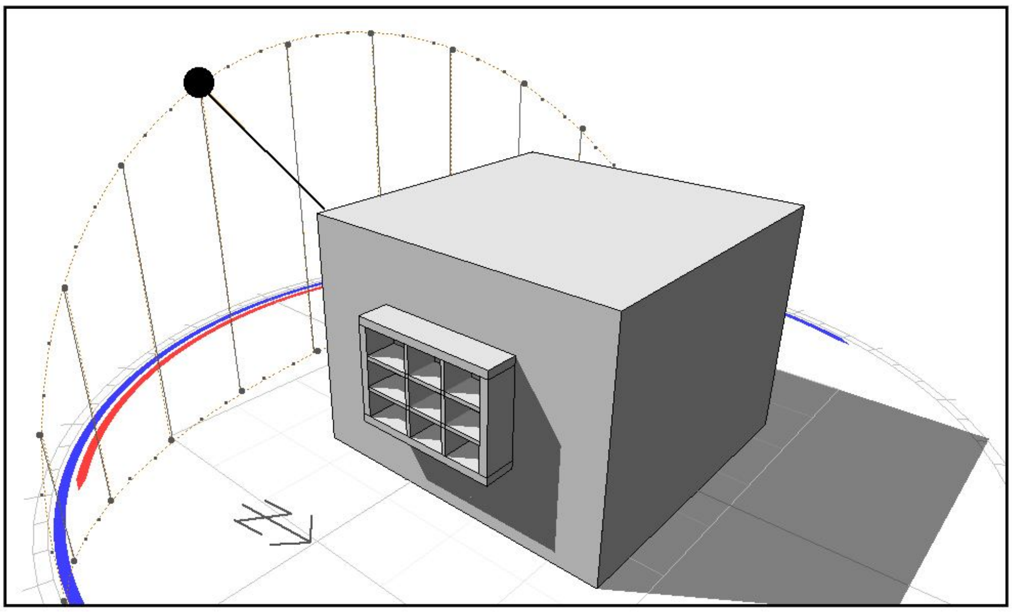


Fig. 5.20 : The shading performance of the optimal depth for east window

5.4. The shading impact of adjacent buildings

The means of shading are not limited only on using shading devices which is mounted on the window, but they also include the shading impact of external elements surrounding the building such as plants and neighboring buildings. This section is carried out to evaluate shading impact of adjacent buildings which is known as overshadowing effect. This effect mainly describes the period when the windows of building is overshadowed by the neighboring existing building. To examine the relation between changing the distance between buildings and shaded percentage on south, west, and east windows. Four adjacent buildings with five floors that is the common height in Gaza Strip have been simulated as shown in fig. (5.21).

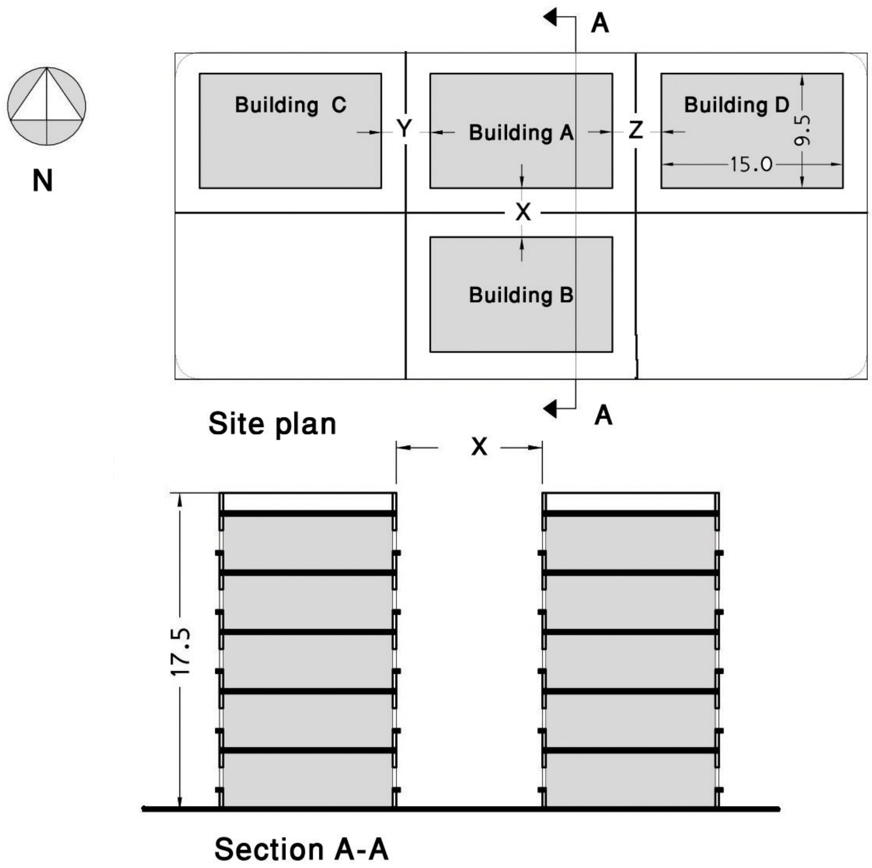


Fig. 5.21 : Site plan and vertical section of simulated buildings

The same design of the building model which has been discussed in previous sections will be also considered in this study. At average hottest day

(30th April) and average coldest day (12th January), the shading impact of building (B,C, and D) on south, west and east facades of building (A) separately will be simulated in next sections using ECOTECT program.

5.4.1 Shading of building (B) on building (A)

This case examine the impact of changing the horizontal distance (X) between building (A) and (B), as shown in fig. (5.22), on the shaded area of south windows of building (A). The result is illustrated in fig. (5.23).

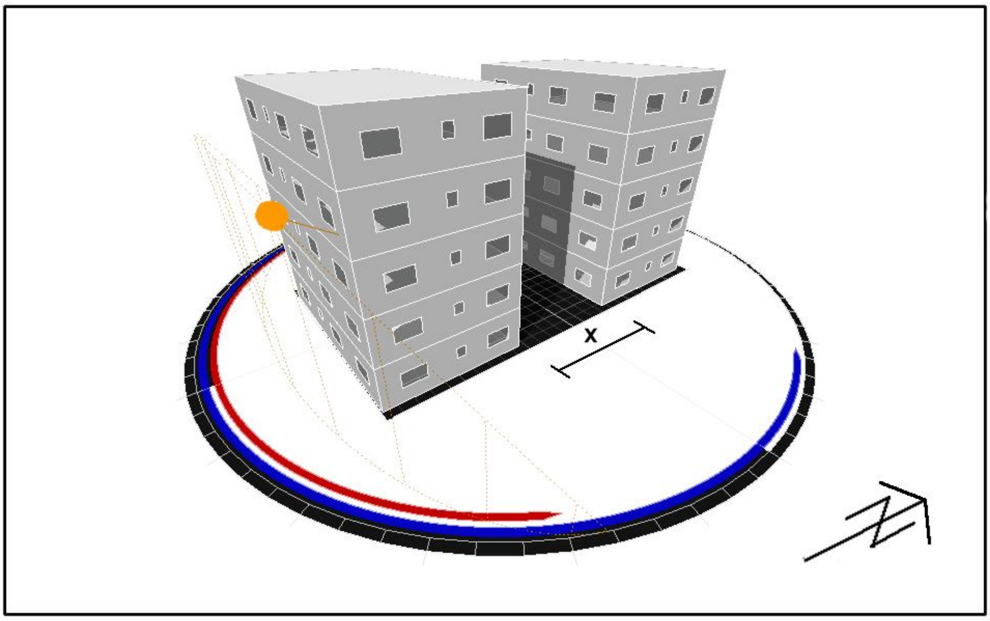


Fig. 5.22 : Overshadowing effect of building (B) on south windows of building (A)

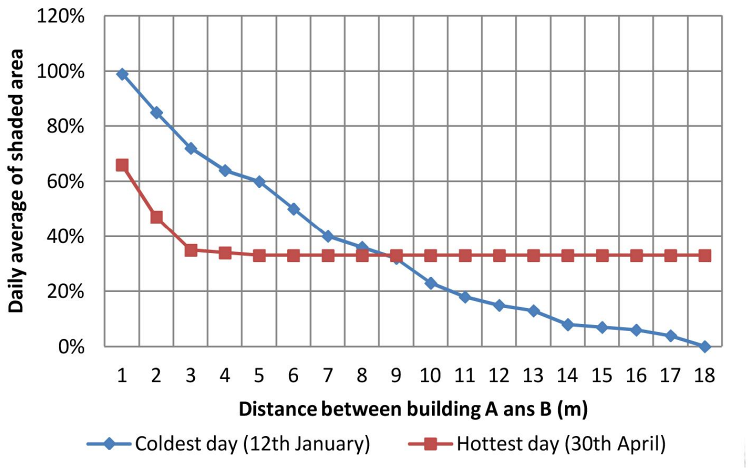


Fig. 5.23: The impact of changing distance (X) on average shaded area ECOTECT

Based on previous results, it is seen that increasing the distance above (3.0m) doesn't give additional shading area in summer, and there is no distance that gives the largest shading in summer and the least shading in winter. Therefore, the shaded percentage above 50% in summer and sunlit area above 50% in winter can be considered as a indicator to select the best distance. It is found that (7.0m) is the best distance for south direction of the building, as it provides 33% shaded area in summer and (60%) sunlit area in winter. This (7.0m) distance is relatively large than the common distance of (4.0) which is used between buildings in the Gaza Strip.

5.4.2 Shading of building (C) on building (A)

Fig. (5.24) shows the shading impact of building (C) on the total windows area of west façade in building (A), see fig. (5.21).

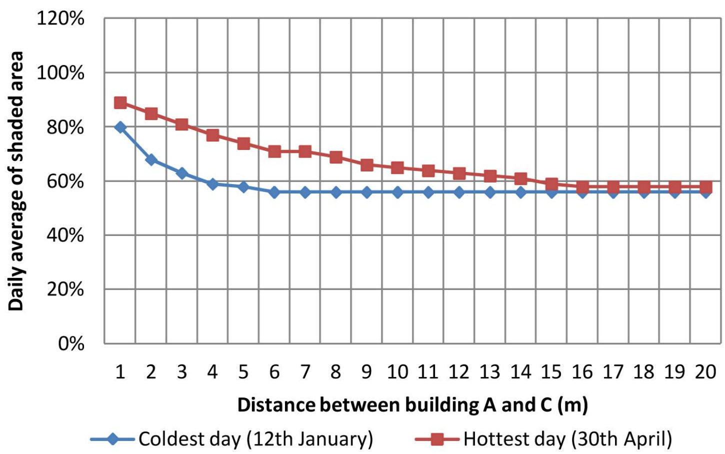


Fig. 5.24: The impact of changing distance (Y) on average shaded area ECOTECT

It is seen that the maximum sunlit area in winter can be obtained at (6.0m) distance. At this distance, the sunlit area in winter reaches (56%), and the shaded percentage in summer is (71%). Therefore, for west direction façade, this distance can be considered the best distance for shading in summer and insolating in winter.

5.4.2 Shading of building (D) on building (A)

Fig. (5.25) shows the shading impact of building (D) on the total windows area of east façade in building (A), see fig. (5.21).

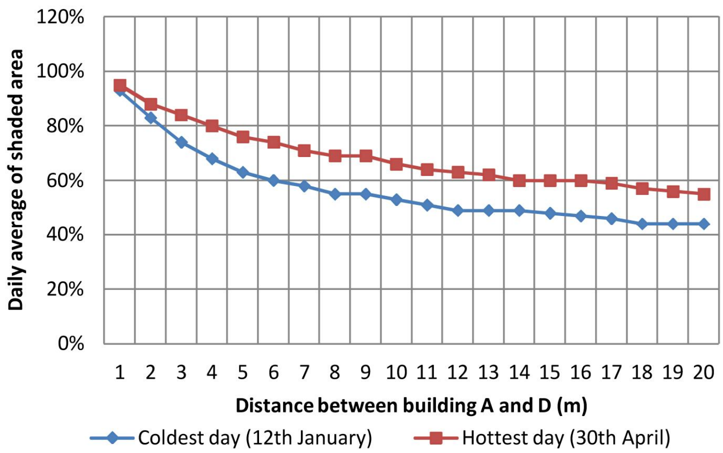


Fig. 5.25: The impact of changing distance (Z) on average shaded area ECOTECT

According to figure, it is seen that shading area is decreased in winter and summer by increasing the distance, and this decreasing rate drop down gradually. Therefore, the shaded percentage above 50% in summer and sunlit area above 50% in winter should be also taken in consideration as a indicator to select the optimum distance.

Thus, it can be found that the (12.0m) is the best distance for east direction of the building, as it gives (51%) sunlit area in winter and (63%) shaded area in summer. It is clear that this optimum distance is largely long than the common distance of (4.0) which is used between buildings in the Gaza Strip.

Conclusion

This chapter is undertaken with the aim of studying the impact of external shading devices on energy demand and finding out the optimum shading device depth. It mainly focuses on south, west and east façade that are exposed to direct solar radiation. For building and room models, only the common used window size with (1.6) width and (1m) height is investigated by Ecotect and IES virtual environment software. Besides shading devices, the overshadowed effect of external of adjacent buildings is also studied in the chapter.

It has been concluded that the optimum horizontal shading device depth of south window that is with 1.0m height and 1.6m width is (0.4m) depth. In addition the optimal horizontal and vertical shading device depth for west window is the depth of (1.9m). For east window, the optimum horizontal and vertical shading device depth is (1.5m) depth. By using the previous optimum depth, it has been found that the heating and cooling energy demand can be reduced by (5.5%) in south direction, by (16%) in west direction, and by (23%) in east direction.

The study also confirms that the overshadowing effect of adjacent buildings can play significant role in shading the windows during summer months. It is found that the optimum distance is (7.0m) for south direction, (6.0m) for west direction, and (12.0m) for east direction.

Chapter

6

Conclusion and Recommendation

Introduction

The thesis is carried out with the main objective to investigate the potential of reducing the energy consumption that is needed in heating and cooling requirements through the appropriate window design. To achieve the purpose of research, four factors which are size, orientation, thermal properties of glass material, and shading device are examined in the climatic condition of the Gaza strip, which is located in hot humid region on longitude 34^0 26' east and latitude 31^0 10' north. The thesis is structured into two parts. First part states a literature review about energy and building, and principles of energy efficient windows. Second part is a parametrical study carried out using "IES VE" and "ECOTECT" programs to investigate the impact of previous four factors on the overall energy consumption of typical residential building model. This final chapter is dedicated to the summarization of the conclusions and recommendations derived from the gathered data and the simulation which is discussed in this study.

6.1. Conclusions

The study can be categorized into three major sections. including energy and its situation in the Gaza strip, low energy building and windows design, and studying the impact of windows design on the overall energy demand. The following is a summary of the conclusions achieved by each of these sections:

6.1.1 Energy and its situation in the Gaza strip

- Energy is essential to economic and social development and improved quality of life as it is used in all aspects of modern life such as transportation, agriculture, industries, buildings.
- World energy demand is expected to increase by about 60% from 2002 to 2030 with an average annual increase of 1.7% per year.
- This steady increasing in energy supply is returned to the population growth which is expected to grow by 3.1% a year on average to 2020, and to economic development which is growing at an annual rate of 1.4% per year.
- The energy resources can be categorized into three sources which are fossil fuels, renewable resources, and nuclear resources. Nowadays, the world mainly depends on the fossil conventional.
- These fossil sources cause several environmental problems such as global warming, air pollution, acid precipitation, ozone depletion, forest destruction and emission of radioactive substances, as a result of gaseous pollutants.
- In light of the negative impact of using conventional fossil fuels, the search for new alternative energy systems instead of conventional fossil fuels is considered urgent need.
- The renewable energy sources appear to be one of the most efficient and effective alternatives. However, in 2010 these sources supplied only about 16.6% of the total world energy demand.
- For the Gaza strip, the main problem of energy is that it has almost no conventional energy sources. This problem becomes worse by the high density pollution and the difficult political procedures of Israel occupation.

- The Gaza strip needs (270) MW of electricity, while the available supply is (197) MW. The large part of this supply about (60%) is provided by Israeli Electricity Company. Locally, about (32%) is provided by Gaza Power Plant. In addition, about (8%) is provided by Egyptian electric company.
- In light of previous statistics, the Gaza strip has been suffering from a real shortage in electricity supply estimated by 25% which affect negatively on Palestinians life and make it very hard.
- Although of this existing problem, the recent exploration of the gas field near the Gaza strip beach can play important role in the solution when it is completely implemented. In addition, the potential of using available renewable energy such as solar and wind energies.

6.1.2 Low energy building with a focus on window design

- Buildings are considered the most significant energy consumers, so there is several attempts to solve the energy problem through design low energy building which is known as energy efficient building design.
- The two objectives of this technique are improving comfort levels of the occupants and minimizing the consumption of traditional energy sources.
- This can be achieved through two approaches which are the active and passive systems. The specific different between them is that the passive system operates on the energy available in its immediate environment while the active system imports energy, such as electricity, to power fans and pumps which make the system work.
- The passive design is the focus of this study, and it can divided into four aspects which are planning principles, building envelope and fenestration principles, passive cooling techniques and passive heating techniques.
- In order to design low energy windows, there is a need to control the heat entering through them. This heat flow can be specified by three factors the thermal transmittance (U-value), solar energy transmittance (g-value), and air leakage (L).

- The solar energy transmittance (g-value) represents the largest source of heat flow. Thus, control the penetration of solar radiation through windows is an essential issue. For this purpose, there are four factors which are window to wall area ratio, orientation, glass material and shading devices.
- Window to wall area ratio is one of the most important factors affects the energy consumption of buildings. Beside solar heat gain, ventilation and daylight also should be taken into account when selecting the optimum window size.
- The orientation of windows is also important for heat gain and loss. They should be oriented according to solar penetration and the prevailing wind .
- The development of advanced glazing materials is considered the main strategy to decrease the heat gain through windows.
- In addition, shading devices can play important role in control the solar radiation. Hence, reducing cooling load which is estimated between 23-89% depending on the type of device used, the building orientation, the climate conditions, etc.

6.1.3 The impact of windows on the overall energy demand

- The energy simulation programs can be considered as a reliable analytical method for building energy research and for evaluation of architectural design in early stages.
- The total heating energy needed to provide comfort throughout the year in the climatic condition of the Gaza Strip which is located in hot humid region is greatly less than the required cooling energy.
- It has been found that the long axis of the building should be elongated along the east-west direction, as it causes the low energy consumption.
- The optimum window size for all facades is the minimum percentage of (10%) from the total wall area. In addition, increasing the window size by 10% leads to increase heating and cooling energy approximately at a steady

rate with linear trend in all facades. This rate is 44% for south window, 16% for west window, 12% for north window, 14% for east window.

- The direct impact of south window is considered the worst, as it causes the large energy consumption. While the north window causes the less impact.
- Besides thermal comfort, it is found that the less window size of (10%) from the total wall area can also offer the best option in terms of visual comfort. In contrast, using large size above 10% shouldn't be selected, because it causes the glare that affects visual comfort.
- It has been also found that the use of a advanced glazing materials with low U-value can play important role in reducing the energy consumption.
- The heating and cooling energy demand of building isn't influenced by the using of vertical shape window instead of horizontal shape.
- In order to design effective shading devices, the overheated period in the Gaza Strip climate can be selected from April to October and between (07:00 AM to 15:00 PM).
- The optimum horizontal shading device depth for south window with (1.0m) height is obtained when it is set as (0.4m). Moreover, installing this optimum horizontal device on window can reduce the heating and cooling energy consumption by (5.5%).
- The optimal horizontal and vertical shading device depth for west window with (1.0m) height and (1.6m) width is (1.9m). The using of this optimum depth can reduce the heating and cooling energy demand by (16%).
- The heating and cooling loads can be reduced (23%) by using the optimum horizontal and vertical shading device depth with (1.5m) on east window that with (0.1m) height and (1.6m) width.
- As a result of studying the overshadowing effect of adjacent buildings on windows, it has been found that this effect can play significant role in shading the windows during summer months. It has been concluded that the optimum distance is (7.0m) for south direction, (6.0m) for west direction, and (12.0m) for east direction.

6.2. Recommendations

In light of the above findings, the following points are recommended:

- Renewable energy sources that are available in the Gaza strip, namely solar and wind energy, should be considered and thought about as potential and clear alternative to solve the problem of energy shortage.
- Because the residential sector consumes the large part of the energy in the Gaza Strip, this sector should be the focus to develop plans and strategies for reducing energy demand.
- Benefit from the successful experiences that are conducted by other countries in energy efficient building and renewable energy techniques.
- Increasing the awareness of architects about the importance of integrating energy efficient building techniques during the different design stages.
- Directing the officials in government to the necessary of developing regulations and standards which ensure the use of energy-efficient principles in building design.
- Using media and school education to assist in increasing the awareness of general public about the dimensions of energy problem and the means of energy conservation which can contribute in the solution.
- Selecting the window type and shape carefully by optimizing the orientation, window size, glasses materials and shading devices, because this can play significant role on the overall energy consumption in building.
- This thesis discussed the effect of window design on thermal performance and daylight level. It is recommended to extend the work carried out in this study by investigating the impact of window design on the performance of natural ventilation system.
- Encouraging researchers to carry out more studies about other factors that help in reducing the energy consumption in buildings such as building form, vegetation, natural ventilation, daylighting, passive cooling etc.

References

Ahsan, T. (2009). "Passive Design Features for Energy-Efficient Residential Buildings in Tropical Climates". MA. thesis, KTH, Department of Urban Planning and Environment, Stockholm University.

Ampofo, F. et al. "Underground railway environment in the UK, Part 1: Review of thermal comfort". Applied Thermal Engineering Journal 24 (2004) 611–631.

Anderson, B. and Riordan, M. (1987). "The New Solar Home Book". Published by Brick House Publishing Company, Andover, MA 01810.

Baker, N. (1987). "Passive and low energy building design for tropical island climates", Martin Centre, University of Cambridge. Prepared for the Commonwealth Science Council by The ECD Partnership, London, UK. Printed and published by the Commonwealth Secretariat.

Bilen, K., et al. "Energy production, consumption, and environmental pollution for sustainable development: A case study in Turkey". Renewable and Sustainable Energy Reviews Journal 12 (2008) 1529–1561.

Bradshaw, V. (2006). "The building environmental: active and passive control systems, third edition". Published by John Wiley & Sons. Inc., Hoboken, New Jersey.

Busato, L. (2003). "Passive cooling and energy efficient strategies for the design of a hotel on the southern coast of Pernambuco, Brazil". MA. thesis, LEARN, London metropolitan University.

Chaiyapinunt, S. et al. "Performance rating of glass windows and glass windows with films in aspect of thermal comfort and heat transmission". Energy and Buildings journal 37 (2005) 725–738.

Chenvidyakarn, T. (2007). "Review Article: Passive Design for Thermal Comfort in Hot Humid Climates", Department of Architecture, University of Cambridge. Published by Journal of Architectural/Planning Research and Studies Volume 5. Issue 1

Datta, G. "Effect of fixed horizontal louver shading devices on thermal performance of building by TRNSYS simulation". Renewable Energy Journal 23 (2001) 497–507.

Demirbas, A. "Potential applications of renewable energy sources, biomass combustion problems in boiler power systems and combustion related environmental issues". Progress in Energy and Combustion Science Journal 31 (2005) 171–192.

Dincer, I. "Renewable energy and sustainable development: a crucial review", Renewable and Sustainable Energy Reviews Journal 4 (2000) 157–175.

Dubois, M. "Simple chart to design shading devices considering the window solar angle dependent properties". Proceedings of the Third ISES Europe Solar Congress: Eurosun 2000, 19-22 June, Copenhagen (Denmark). (cd-rom chapter 16 : Windows).

Etzion, Y. and Erell E. "Controlling the transmission of radiant energy through windows: a novel ventilated reversible glazing system". Building and Environment journal 35 (2000) 433±444.

Geun, K. (1997). "An Assisted Dwelling Facility for the Elderly in Lubbock, Texas". MA thesis, Architecture Faculty, the College of Architecture of Texas Tech University.

Giridharan, R. et al. "Lowering the outdoor temperature in high-rise high-density residential developments of coastal Hong Kong: The vegetation influence". Building and Environment Journal 43 (2008) 1583–1595.

Gosselin, J. & Chen, Q. "A computational method for calculating heat transfer and airflow through a dual-airflow window". Energy and Buildings 40 (2008) 452–458.

Gustavsen, A. et al. (2007). "State-of-the-Art Highly Insulating Window Frames – Research and Market Review". Project report supported by the Assistant Secretary of Energy Efficiency and Renewable Energy, and by the Research Council of Norway.

Gustavsen, A. (2001). "Heat Transfer in Window Frames with Internal Cavities". MA thesis, Department of building and construction engineering, Faculty of civil and environmental engineering , Norwegian University of Science and Technology, Trondheim, Norway.

Gutierrez, G. and Labaki, L. "An Experimental Study of Shading Devices: Orientation Typology and Material". Presented at International Conference of Thermal Performance of Exterior Envelopes of Whole Buildings, 10th, 2007, Clearwater Beach. Proceedings... Clearwater Beach, Florida: ORNL/ASHRAE.

Halder, V. (2007). "Upgrading a Broad Area Illuminating Integrating Sphere and Solar Transmittance Measurement of a Sheer Blind". MA thesis, Mechanical Engineering, University of Waterloo, Waterloo, Ontario, Canada.

Jaber, S. and Ajib, S. "Optimum, technical and energy efficiency design of residential building in Mediterranean region". Energy and buildings Journal 43 (2011) 1829–1834.

Jackson, G. et al. (1999). "Daylighting and window design". Published by The CIBSE: Chartered Institution of Building Services Engineers in association with the Department of Environment, Transport and the Regions' Partners in Technology.

Ingersoll, T. et al. (1974). "manual of tropical housing and building- part one: climatic design". London: Longman, Third impression. The book was first published in 1974.

Jonsson, A. (2010). "Optical characterization and energy simulation of glazing for high-performance windows". PhD thesis, Faculty of science and technology, University of Uppsala.

Kaklauskas, A. et al. "Selection of low-e windows in retrofit of public buildings by applying multiple criteria method COPRAS: A Lithuanian case". Energy and Buildings Journal 38 (2006) 454–462.

Kalogirou, S. "Environmental benefits of domestic solar energy systems", Energy Conversion and Management Journal 45 (2004) 3075–3092.

Kandeel, E. (2010). "Energy-Efficient Building Design Strategies in Gaza Strip: With Reference to Thermal Insulation", MA thesis, Faculty of Engineering, Islamic University, Gaza, Palestine.

Karlsson, J. (2001). "Windows – Optical Performance and Energy Efficiency". PhD thesis, Faculty of science and technology, University of Uppsala.

Karlsson, J. et al. "A simple model for assessing the energy performance of windows". Energy and buildings Journal 33 (2001) 641-651.

Kasule, S. (2003). "Daylighting and Sun-shading in Buildings in Tropical Regions: An Example of Virika Hospital, Kasese, Uganda". PhD thesis, Faculty of Building (Civil Engineering and Architecture), Germany.

Khan, N. et al. " review on wind driven ventilation techniques". Energy and Buildings Journal 40 (2008) 1586–1604.

Majumda, M. (2002). "Energy-efficient building in India". Published by Tata Energy Research Institute, Darbari Seth Block, India.

Marrero, A. and Oliveira, A. "Effect of louver shading devices on building energy requirements". Applied Energy Journal 87 (2010) 2040–2049.

Mathur, K. and Chand, I. (2003)."Climatic Design for Energy Efficiency in Buildings". Central Building Research Institute. This paper was presented at the 18th National Convention of Architectural Engineers held at Jaipur on October 17-18, 2002.

Mazria, E. (1979). "The passive solar energy book: a complete guide to passive solar home, greenhouse and building design", Published by Rodale Press, Inc., 331East Minor Street, Emmaus, PA 18049 USA.

McKay, S. and Consultant, S. (2010). "Review of technologies and approaches for new developments". published by AECOM House, 63-77 Victoria Street, St. Albans, Herts, AL1 3ER.

Ministry of Local Government, (2004). "The Palestinian Code of Energy Efficient Buildings. Ramallah": Ministry of Local Government.

Monna, S. & Masera, G. (2010). "Intelligent Tall Building Envelope Technologies and Design Alternatives for Comfort and Energy Efficiency in Hot, Arid Climate". Building Environment Science & Technology Department, Polytechnic of Milan University.

Moore, F. (1993). "Environmental Control Systems: Heating, Cooling, Lighting". Published by McGraw-Hill Education (ISE Editions).

Muhaisen, A. (2007). "The Energy Problem in Gaza Strip and its Potential Solution". Proceedings of Energy and Environmental Protection in Sustainable Development (ICEEP), Hebron, Palestine, May 2007. Hebron: Palestine Polytechnic University, p. 145-153.

Persson, M. et al. "Influence of window size on the energy balance of low energy houses". Energy and Buildings Journal 38 (2006) 181–188.

Panwar, N et al. "Role of renewable energy sources in environmental protection: A review", Renewable and Sustainable Energy Reviews Journal 15 (2011) 1513–1524.

Olbina, S. (2005). "Decision-Making Framework for the Selection and Design Of Shading Devices". PhD thesis, Environmental Design and Planning Department, Faculty of the Virginia Polytechnic Institute, State University.

Omer, A. "Renewable building energy systems and passive human comfort solutions". Renewable and Sustainable Energy Reviews journal 12 (2008) 1562–1587.

Oral, G. and Yilmaz, Z. "Building form for cold climatic zones related to building envelope from heating energy conservation point of view". Energy and Buildings Journal 35 (2003) 383–388.

Palestinian Energy Authority (PEA), 2011. Renewable Energy Department: Climate Data [online]. Available at: "http://pea-pal.tripod.com/renewable_energy_department.htm#&%20Climate%20Data" [Accessed 25 April. 2011].

Persson, M. (2006). "Windows of Opportunities: The Glazed Area and its Impact on the Energy Balance of Buildings". PhD thesis, Faculty of science and technology, University of Uppsala.

Salameh, M. "Can renewable and unconventional energy sources bridge the global energy gap in the 21st century?". Applied Energy Journal 75 (2003) 33–42.

Sen, Z. (2008). " Solar Energy Fundamentals and Modeling Techniques: Atmosphere, Environment, Climate Change and Renewable Energy". Istanbul Technical University Faculty of Aeronautics and Astronautics, Dept. Meteorology, Campus Ayazaga, 34469 Istanbul, Turkey.

Solangi, K. et al. "A review on global solar energy policy". Renewable and Sustainable Energy Reviews Journal 15 (2011) 2149–2163.

Szokolay, S. (2007). "Design Tools and Techniques: Solar Geometry". Published by PLEA: Passive and Low Energy Architecture International in association with Department of Architecture, The University of Queensland, Brisbane 4072.

Szokolay, S. (2004). "Introduction to architecture science: the basis of sustainable design", Published by Architectural Press, An imprint of Elsevier Science.

Urbikain, M. & Sala, J. "Analysis of different models to estimate energy savings related to windows in residential buildings". Energy and Buildings journal 41 (2009) 687–695.

Vogel, V. (2004). "Solar Heat Gains and Daylight Factors – An Analysis of Effective Shading Techniques". MA thesis, Building and Management, University of Exeter.

Werner, A. (2007). "External Water Condensation and Angular Solar Absorptance: Theoretical Analysis and Practical Experience of Modern Windows". PhD thesis, Faculty of science and technology, University of Uppsala.

Yuksel, I. "Global warming and renewable energy sources for sustainable development in Turkey". Renewable Energy Journal 33 (2008) 802–812.